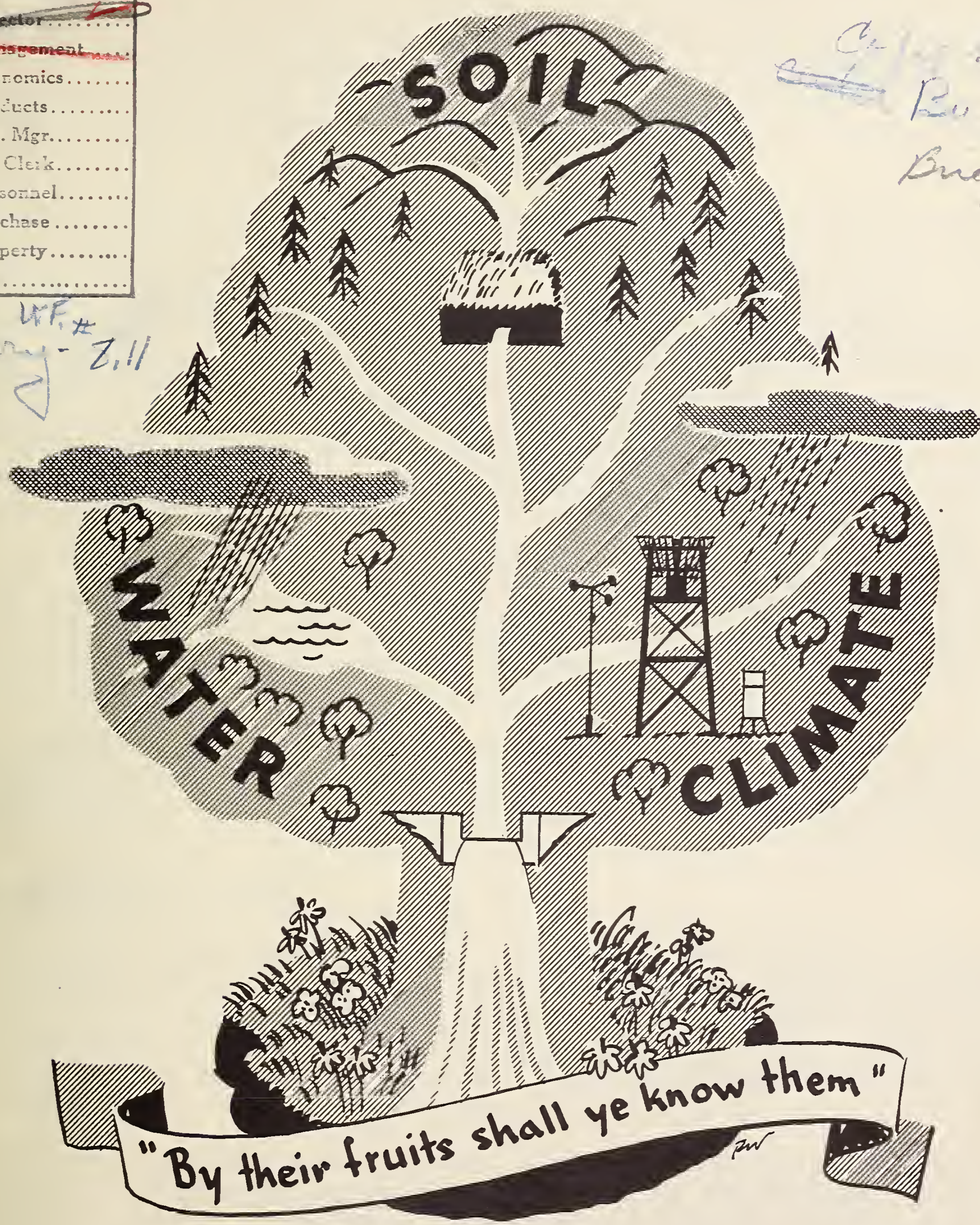
DIVISION OF FOREST INFLUENCES

Quarterly Report



U. S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

January-March 1953

5077

QUARTERLY PROGRESS REPORT
Division of Forest and Range Influences

January-March 1953

General

During and since the three-month period covered by this report, two important events occurred which will have a profound effect on the future form and contents of these reports. Although they apply more to the next report than to this one, they deserve some discussion as a picture of shaping policy, and as a guide to the preparation of future reports.

First is metamorphosis in organization of flood-control surveys, both within and outside the Forest Service. As instructed by Secretary's Memorandum 1325, the Soil Conservation Service is now assuming leadership on all flood control survey work. Along with this change of responsibilities, the Forest Service carried through a step which had been contemplated for some time: the transfer of flood control survey work from Research to the Branch of State and Private Forestry. Flood prevention and basin activities have been set up under a new division, with Mr. Warren T. Murphy as Chief. His responsibilities include action programs as well as surveys. Under Mr. Murphy's leadership, Ilch and Morey are continuing their past fine work in flood control activities.

As an incidental but important feature, future reports of the Division of Forest and Range Influences will not include discussions of flood control activities. We shall miss these flood control statements; they have invariably been constructive and interesting, and have contributed to the value of the Quarterly Reports.

The second new development is the decision of the Directors, at the Regional Foresters-Directors meeting this spring, to change the Forest Influences reports from a quarterly to a semi-annual basis. Accordingly, this is the last of our quarterly reports; the next one will be due October 1, 1953.

Washington Office Notes

During this quarter there has been a continuation of the growing expressions of interest outside the Forest Service, on the water relations of forest and rangelands and practices. Many inquiries come in, from both inside and outside the United States. In rather natural contrast, the principal interest of Forest Service people in Washington is in the policies involving watershed relations rather than the practices.

During recent months, the Division of Forest and Range Influences has, however, been able to give substantial assistance to the interests of our flood prevention people, in two ways. First, we have taken a leading part in the activities of the Subcommittee on Hydrology of FIARBC, in planning for a

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hydrologic evaluation project to be sponsored by Federal agencies. Second, we have taken active part in discussions of the validity of hydrologic evaluation techniques employed by the Forest Service.

In other fields of interest, consultation has been continued on the Waterways Experiment Station Cooperative Infiltration project at Vicksburg, Mississippi. Also, Wilm has been called upon as a consultant on a broader study of environmental factors.

The Division has made excellent use of many color slides, from collections sent us by the experiment stations. A large number of copies have been made, and are now filed in organized sequence with all the necessary descriptions. Thus they are available and have already been used several times to illustrate discussions of forest and range influences research on a nationwide basis.

A beautifully illustrated booklet is being prepared by the Division of Information and Education, to accompany the moving picture, "Waters of Coweeta." We have given all possible support to this work. Also, the Division has assisted in preparing material for a prospective campaign on watershed conservation, sponsored by the National Advertising Council. Finally, we have prepared a list of suggested discussion topics for the coming "White House Conference" on Resources for the Future.

In the way of personal notes, Wilm was elected President of the Section of Hydrology, American Geophysical Union; and Member of the Eastern Advisory Board of the Biometric Society. More recently, he has accepted a position as Associate Dean of the New York State College of Forestry, Syracuse, New York. While looking forward to the pleasure of the new position, he wants to express to all of you his very sincere and strong regrets at leaving the Forest Service, and especially the Division of Forest and Range Influences. Our Division represents a fine group of research men who need to take a back seat to no one in the biological sciences as to the quality of their contributions to scientific knowledge.

QUARTERLY REPORT, January - March, 1953

San Dimas Research Center
Forest Influences Division
California Forest and Range Experiment Station

GENERAL

During the last three months Sinclair has been working on a committee of four designated to formulate policies for the management of national-forest lands in southern California. L. A. Rickel, supervisor of the Los Padres National Forest, is chairman of the committee. Other members are: George W. Armstrong, Angeles National Forest; and E. J. Jensen, Regional Office. The group completed a report which is now being reviewed within Region 5 and the California Station.

Two of the Influences men in California have been elected to posts of responsibility in the San Francisco Bay Section, Soil Conservation Society of America. Clark Gleason is the new chairman of the group, and Ed Munns is a member of the 5-man Advisory Council. The thirty Section members are well along in a study of practical watershed management. Last year they took up the water and sediment problems of a single small drainage, the Walnut Creek watershed, in central California. This year they are studying technical and economic problems of managing vegetation, soil, and water on wildlands throughout the State. Papers presented at the meetings will be submitted for publication in the Journal of Soil and Water Conservation.

SAFETY

On January 12 a safety meeting was held at Tanbark Flat (San Dimas Experimental Forest) to discuss: (1) Field work hazards and action needed to reduce these hazards, and (2) work habits and action needed to bring about safer work habits. The meeting was attended by the outgoing and incoming Experimental Forest safety officers, and field workers. The present status of the San Dimas safety program was outlined for the information of the new officers.

Mrs. Waite, assistant safety officer, has completed a report on hazard reduction over the San Dimas Experimental Forest during the quarter.

MANUSCRIPTS IN PREPARATION

The manuscript "Hydrologic analysis used in determining fire effects on peak discharge and erosion rates in southern California" has been reviewed by Rowe and Countryman and submitted to the Station editor for review.

Data analyses have been completed for the paper "Effects of the forest floor from pine on disposition of rainfall" by P. B. Rowe.

"The development of vegetation after fire in the chamise chaparral of southern California" by Horton and Kraebel was revised by the coauthors and reviewed by Colman.

"Temperature requirements for germination in relation to wildland reseeding" by Ashby and Hellmers has been further revised following staff review.

"Root systems of some chaparral species" by Hellmers, Juhren, Horton, and O'Keefe is being revised by the authors.

"Rainfall sampling on rugged terrain" by E. L. Hamilton was revised and has been sent to the Station editor for review.

Sinclair drafted a paper titled "Erosion in the San Gabriel Mountains of California" for a symposium planned by the Land Erosion Committee of the American Geophysical Union.

A publication plan and work outline for "Additional information on the installation and use of the fiberglas soil moisture units" by Horton was reviewed by the San Dimas staff and submitted to Berkeley. This paper will be issued as a set of instructions for use of those installing these instruments.

A publication plan and work outline for "Preliminary information obtained from the San Dimas lysimeters" by Horton was reviewed by the San Dimas staff and submitted to Berkeley.

A draft of "Suspended sediment as related to watershed streamflow, soils, topography, and land use" by H. W. Anderson, has been prepared for presentation at the Symposium on Erosion to be held at the Annual Meeting of the Amer. Geophys. Union. (Abstract of paper given in Flood Control Survey Quart. Rpt., Apr.-June, 1952.)

"Measuring the hydrologic potential of watersheds and the effects of treatment" by H. W. Anderson is being prepared for presentation at the Berkeley meeting of the local Chapter, Soil Conservation Society of America, April 13. This paper summarizes the measures which express the hydrologic potential of watersheds, the methods of evaluating such measures, and the effects on such measures of fire in southern California and logging in western Oregon.

"Detecting hydrologic effects of changes in watershed conditions" by H. W. Anderson has been rewritten for publication and revised in the light of technical review. An additional test has been incorporated to detect changes in total annual flow following major wildfires in the Santa Ynez watershed. No change in the total annual flow could be detected by the "double-mass" plotting technique. The idea that appreciable amounts of water may be saved simply by burning off the brush, therefore, appears to be open to serious question in this area. This

paper was presented by Anderson at the Stanford meeting of the South Pacific section, American Geophysical Union, February 6, 1953.

"Flood frequencies and sedimentation in southern California" by H. W. Anderson, is in the process of technical review. The paper summarizes estimates of sedimentation rates and peak flow frequencies under various fire protection levels, the estimates having been made in connection with Flood Control Surveys of some southern California watersheds.

CURRENT RESEARCH

SNOW STUDIES

Some preliminary investigations of the relation of forests to snow water storage and ablation* have been started, using data collected by the staff of the Central Sierra Snow Laboratory since 1946. These investigations have for their purpose:

(1) Development of some sensitive measures for characterizing forest conditions as they influence snow pack accumulation and ablation.

(2) Preliminary evaluation of the magnitudes of the effects on the snow pack of various forest conditions which simulate possible forest treatments.

(3) Formulation of hypotheses which will be worth testing should the Division be able to start formal research in snow pack management.

Examinations of the rate of snow ablation and the date when snow disappears have been started for the individual point measurements of snow within snow courses. An attempt will be made to relate snow ablation and the time of final disappearance of snow to tree shade, tree-induced interception and melt, and tree effects on wind. As an example of the order of magnitude of the forest effects, the data for one snow course in the year 1950 may be cited: On April 11 the snowpack water equivalent at four forest-shaded points ranged from 57 to 60 inches and at two open points from 54 to 58 inches. From that date until about May 10, snow ablation in the forest shade averaged 5 inches of water, while ablation in the open was 14 inches. From May 11 until all snow was gone, the ablation rate in the forest was about two-thirds that in the open. When all snow was gone in the open (June 3-5), 24 to 30 inches of water equivalent remained in the forest. Six to 13-1/2 inches of water remained in the snowpack in the forest 16 days later (June 20), and final disappearance of the snow from the forest ranged from June 25 to July 5. These results suggest that the influence of forest cover on snow ablation may be of importance to water supply and flood control in the State.

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*Ablation is used here to mean the decrease in the water equivalent of the snow pack; it equals the net effect of precipitation, melt, and evaporation during the ablation period.

Rainfall

The 1952-53 rain season with 13.33 inches of rainfall at Tanbark Flat as of April 1 has reverted to the low rainfall condition of the four years preceding 1951-52. Strangely enough, the present season is very similar to the 1941-42 season in quantity and distribution of rainfall while last year paralleled 1940-41.

Rainfall by 3-month periods shows the following trends:

	Oct.-Dec.	Jan.-March	Balance of year	Total
1952-53	8.94	4.39	?	?
1941-42	9.08	3.77	1.83	16.68
24-year average	9.11	15.66	3.47	28.24

The 3-month period January-March is the heart of the southern California rain season and should produce 55 percent of the annual precipitation. The present season's deficiency has been equalled only by the 1884-85, 1909-1910, and 1941-42 seasons according to the 72-year West rain gage record at Glendora. Even 1898-99, the lowest year of record, had about seven inches of rain during this quarter. Of course in '98-'99 they had only nine inches all year. The indications are that total rainfall for 1952-53 will amount to about 15 inches or about one inch less than the average of the four subnormal years 1947-1951.

Streamflow

Streamflow continues at all of the major watersheds and the Bell small watersheds but the flows are very low for this time of year. They range from 0.06 c.f.s. in watershed IX to 1.66 c.f.s. at No. VI gaging station. There is no flow in the Fern small watersheds and only .002 to .008 c.f.s. in the Bell small watersheds.

Lysimeters

Soil moisture samples were taken from each lysimeter containing fiberglas moisture units for the purpose of field calibration of the units. A start has been made in correcting the soil moisture readings taken by the fiberglas units to the standard temperature of 60°F.

Results in the confined and unconfined lysimeters for the 1952-53 season through March 23 are summarized in the following tables, together with a comparison of results in other years. Most of the runoff on the lysimeters occurred in the 1.71-inch storm of December 1, 1952, which had a 5-minute intensity of 2.76 inches per hour and an hourly intensity of 0.67 inches per hour.

Type of cover	Confined lysimeters				
	Runoff 1952-53	Seepage 1952-53	Runoff as pct. of annual precip.		
			1952-53	1951-52	1948-51 4-yr. avg.
	----- inches ----				
Bare	8.0	0	58	69	53
Grass[1/]	1.4	0.8	10	41	-
Buckwheat	1.1	0	8	39	17
Chamise	2.6	0	19	42	24
Ceanothus	1.5	0	11	41	26
Sugarbush[2/]	2.7	0.8	20	42	-
Scrub oak	.9	0	6	43	21
Coulter pine	3.3	0	30	45	29

1/ Vegetation planted early in 1951.
2/ Vegetation planted in winter of 1951.

In the confined lysimeters, runoff as percent of rainfall was lower this year than last. This was due, at least in part, to rainfall differences, for in 1951-52 rainfall was 41.1 inches, three times as much as this year. Analysis of infiltration rates will be needed to determine whether the growing vegetation has also been responsible for changed runoff quantities. It will be noted that runoff this year was greatest on the bare lysimeter, and that the next highest runoff was shown by the lysimeters planted to Coulter pine. The pine lysimeters have produced less litter than those supporting buckwheat, chamise, ceanothus, or oak. It may be that the sparse soil cover so far provided by the pines is related to the higher runoff occurring on these lysimeters.

Moisture penetration in the confined lysimeters varied with weather and cover conditions. Above-normal temperatures and lack of rainfall after the first of the year accelerated the drying of the soil, so that moisture penetrated only 24 inches in the chamise, ceanothus, and pine tanks, and 33 inches in the buckwheat and oak tanks. Lysimeters recently planted to grass and sugarbush, were wet through the entire 6 feet of soil and seepage occurred. The grass lysimeters have had only a sparse vegetative cover until this spring, when the cover thickened appreciably. The sugarbush plants are still small, and provide only scattered and light cover. These conditions resulted in less evapo-transpiration last summer under grass and sugarbush than occurred in lysimeters planted to other species. As a consequence, these lysimeters have yielded seepage this year while the others have not.

Type of cover	Unconfined lysimeters		
	Runoff	Runoff as pct. of annual precip. 1952-53	Runoff as pct. of annual precip. 1951-52
	inches		
Buckwheat	0.11	0.8	29
Chamise	0.72	5.3	27
Ceanothus	0.52	3.8	39
Scrub oak	0.39	2.8	46
Coulter pine	3.69	26.9	44

In the unconfined lysimeters, the runoff percentages were also much lower this year than in 1951-52. Again, the greatest runoff occurred under pine cover. Moisture penetration in these lysimeters was 20 inches under Coulter pine, 25 inches under chamise, 36 inches under buckwheat and ceanothus, and 41 inches under oak.

Rainfall Disposition

Tanbark Plots.--Soil moisture samples were taken in the brush and pine plots for the purpose of field calibration of the fiberglas units.

Specifications were prepared and bids let for the fabrication of interceptor rings for use in obtaining grass interception measurements.

Cover Improvement Project

Soil Studies

Work continued on finding a practical design for a collector of side-slope sediments. The most promising type, at least for a small number of installations, appears to be one built of a combination of 8-inch diameter U-shaped, steel flume sections, and soil cement, an idea of Charles Young, Arcadia Soils Laboratory. Clearances have been given to use a considerable amount of steel flume now stockpiled at the Los Angeles River Flood Control Project office at Oak Grove Park. The Angeles National Forest is also supplying a crew of three men to assist with the installation of these collectors at field study locations.

Considerable time has been given to locating satisfactory study sites in the Los Angeles River watershed. Only a few installations can be made this season, and care is being exercised to select locations for these that will represent typical slope, soil, and vegetative conditions. Several sites have been selected, and installation of the collector trough was started at one of these on March 23.

A draft of the work plan for the soil movement study was completed.

Plant Physiology

Soil Adaptability.--Analysis has been completed of the growth data for five grass species on soils derived from three principal parent materials (Wilson diorite, Lowe granodiorite, and anorthosite) in the Los Angeles River watershed. The data show growth of these grasses to be statistically better (at the 1-percent level of significance) on the Wilson diorite than on the Lowe granodiorite. Growth was similarly better on the anorthosite than on the Lowe granodiorite for *Bromus rigidus*, *B. stamineus*, *Melica imperfecta*, and *Phalaris tuberosa* var. *stenoptera* but not for *Ehrharta calycina*. Statistically significant differences were not shown between the Wilson diorite and the anorthosite. New species started in this study are *Cytisus canariensis*, *Lotus berthelotti*, *Calycotome villosa*, *Retama roetam*, *Cassia acuta*, and *Sophora tetraptera*.

Growth Studies.--Species grown during the past year have been classified with respect to their growth at several temperatures (Quarterly Report, October-December, 1951). The categories and species are:

A. Species whose growth at all temperature conditions falls within 33-167 percent of average growth.

   Baccharis pilularis ssp. *typica*
   Bromus rigidus
   Bromus stamineus
   Ehrharta calycina
   Lolium multiflorum
   Lotus mascaensis
   Lygeum spartum
   Phalaris tuberosa var. *stenoptera*

B. Species whose growth is favored by low temperatures.

   Lotus berthelotti

C. Species whose growth is favored by moderate temperatures.

   Brassica nigra
   Cytisus canariensis
   Melica imperfecta

D. Species whose growth is favored by high temperatures.

Dodonaea viscosa var. *angustifolia*
Forestiera neo-mexicana
Rhus laurina
Rhus ovata

New species now in this study are *Aristotelia maqui*, *Spartium junceum*, *Cneoridium dumosum*, *Retama roetam*, *Sophora tetraptera*, and *Quercus dumosa*.

Correction.--In the October-December Quarterly Report a misleading statement was made regarding conditions necessary for the germination of smilo seed. Actually, smilo will germinate at low temperatures as well as high ones, but germination is slowed considerably when temperatures are low. In California, dry periods of two to three weeks are fairly common during the rainy (cool) part of the year. If germination is not quick at this time the surface soil may dry before the seedlings have sent roots to greater depths, resulting in their death. The ability of seeds to germinate quickly at high temperatures is of no particular advantage, under uncultivated conditions here, because during summer when air temperatures are high there is ordinarily no water available to plants--or for seed germination--in the surface soil.

MEETINGS

January 19.--Gleason gave an illustrated talk on watershed management to the class in Conservation at San Jose State College.

February 4.--Explorer Post 300, Boy Scouts of America, was introduced to some problems of watershed management by Gleason, speaking informally with kodachromes. Purpose of the meeting was to give the scouts information which they could use in displaying Influences photo enlargements and other conservation materials at the Orinda area exposition in celebration of National Boy Scout Week.

February 6.--Colman, Anderson, and Gleason attended the American Geophysical Union meeting at Stanford University.

February 26-27.--Gleason attended the annual meeting of the California Association of Soil Conservation Districts, hels in San Diego.

March 5 and 9.--"Waters of Coweeta" was given its first California showings, to the Station staff and guests, and to the San Francisco Bay Section, Soil Conservation Society of America.

COOPERATION

Agricultural Extension Service.--Working with A. E. Weislander of the Forest Survey Division, a map was prepared showing the principal areas of California in which brush constitutes a range problem on watershed land. The map was made at request of the Agricultural Extension Service for use in their forthcoming motion picture "Hills of Grass" on the conversion of brush cover to grass. Made by grouping the woodland and brush types shown on Forest Survey's Vegetation Type Map prepared from air photos in 1945, the current map defines 9 million acres of woodland types and 11 million acres of brush types as the gross area within which some amount of cover conversion work may be necessary or desirable from a range standpoint.

U. S. Bureau of Reclamation.--Assistance was given to Mr. Lee Hill and his staff in statistical evaluation of the flow of the San Joaquin River below Friant Dam.

Corps of Engineers.--Anderson talked over analyses being made by Mixsell and Humphrey of the Corps on snow pack water equivalent as related to terrain characteristics. Anderson agreed to investigate the possibility of setting up some more sensitive variables representing forest condition.

Division of Range Research.--R. L. Hubbard of the Berkeley office worked several weeks calibrating soil moisture units and preparing them for installation. These units are to be placed in several experimental areas in northern California where the California Station, in cooperation with the California Division of Fish and Game, is studying the factors influencing the survival of bitterbrush in winter deer ranges. Horton went to Bishop with Hubbard to help install the first stack of units.

Los Angeles River Flood Control Project.--Ray Dalen, of the Forest Service, conferred with Rowe and other members of the San Dimas staff on methods of determining effects of fire on flood discharge and erosion rates in the Arroyo Seco watershed.

Johns Hopkins University.--A short list of selected references and information concerning methods of hydrologic analysis for evaluating influences of land management on streamflow were sent C. R. Forsberg, in response to his request for this material.

VISITORS

BERKELEY

March 13.--Mario Habit, of Chile, discussed forest and range influences problems with Gleason. Of special interest was Habit's statement that severe wind erosion occurs in the grasslands of Tierra del Fuego, on areas covered with bunchgrass clumps only one to two feet apart.

March 20.--Carl Miller of Bureau of Reclamation, Denver office, called to discuss estimation of sediment production in the Santa Ynez watershed.

SAN DIMAS

January 9.--Robert W. Cowlin, Director, Pacific Northwest Experiment Station.

January 27.--A. L. Hormay and D. R. Cornelius of the Range Research Division, and George Burnett, Assistant Chief, Range Management for Region 5.

February 3.--Prof. Lloyd of California Polytechnic Institute, San Dimas, and thirty students.

February 19-20.--John H. Dorroh, Jr., Chief, Hydrology Section, Southwest Region, Soil Conservation Service, Tucson, Arizona; Joel Fletcher, Research Supervisor, Soil Conservation Service, Tucson, Arizona; R. B. Hickok, Research Supervisor, Soil Conservation Service, Albuquerque, New Mexico; and Willis Barrett, Hydrologic Engineer, Soil Conservation Service, State College, New Mexico. These men also visited the Berkeley office.

February 20.--L. N. Ericksen and Forest Products Laboratory guest.

February 20.--DeWitt Nelson, California State Forester, and James Mace, Deputy State Forester.

February 24.--Don Turner, Engineer of the Trinity National Forest; Jack Fisher of the Forest Service Soils Laboratory at Arcadia, California.

February 27.--Mr. and Mrs. H. D. Waring, Commonwealth Forestry Service, Canberra, Australia. Mr. Waring also spent considerable time at the Berkeley office during the last few months.

DISCUSSION

Discussion of RMF&RES, FI Rpt., Oct. to Dec. 1952, Infiltration Research:

Since infiltrometer measurements are still being made by research men it might be worth-while discussing (1) what are the variables which define an infiltration curve? and (2) what indexes might be available from infiltrometer measurements which would indicate treatment effects:

Some variables which might be defined are:

P = the rainfall rate, inches per hour

t_0 = time from start of rain until start of surface runoff, minutes

t_i = time from start of rain, minutes

f_c = infiltration capacity, inches per hour

f_i = infiltration rate at time t_i, inches per hour

K_f = a constant representing the rate of change of infiltration with time.

xP = precipitation excess, inches per hour

d = surface detention, inches

q_s = rate of surface runoff, inches per hour

S = soil storage, inches

q_L = lateral discharge (for watersheds is total discharge minus q_s), inches per hour

K_d = & C_d = constants in equation relating d to t_i and q_s

Some functions needed:

$$t_0 = \text{function } (P, \text{soil, treatment, vegetation}) \quad (1)$$

$$f_i = f_c + (f_0 - f_c)\, e^{-K_f t} \quad (2)$$

$$K_f = \text{function (soil, treatment, vegetation, } P) \quad (3)$$

$$f_c = \text{function (soil, treatment, vegetation)} \quad (4)$$

$$d = C_d q_s^{K_d t} = \text{function (vegetation, treatment)} \quad (5)$$

$$q_L = \text{function (plot size, wetted border, soil, } f_i) \quad (6)$$

VISITORS

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Some functions needed:

$$t_0 = \text{function (P, soil, treatment, vegetation)} \quad (1)$$

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$$f_c = \text{function (soil, treatment, vegetation)} \quad (4)$$

$$d = C_d q_s^{K_d t} = \text{function (vegetation, treatment)} \quad (5)$$

$$q_L = \text{function (plot size, wetted border, soil, } f_i\text{)} \quad (6)$$

It would seem that evaluation of constant K_f of equation (2), in the form of equation (3) would be better than using the "Time from start of run to stability" which was reported. Ordinarily the selection of the time that stability is reached for curves which approach stability asymptotically is rather uncertain. The idea of evaluating the independent effects of "soil", "vegetation" and "treatment" on characteristics of the infiltration curve seems like a very useful one. For regression analysis tests it might be well to set up a study in which these were present in combinations of their extremes. Some indexes of the constants of equation (5) should be forthcoming from infiltrometer measurements, particularly for those vegetation types for which the runs may be made without disturbing the vegetation. (H. W. Anderson).

BI-ANNUAL REPORT OF FLOOD CONTROL SURVEY DIVISION

Intermountain Forest and Range Experiment Station

January - March 1953*

Columbia Basin

With the exception of about one man-month devoted to the Colorado portion of the AWR, all of the available time of the division was spent on the CBCAP. Intermountain's commitments for the basinwide report were largely completed prior to January 1 and most of the time during this quarter was spent on the Middle Snake River (Area I) supplemental report. While the principal responsibility for drafting this report was assigned to Croft of R-4, many individual assignments had previously been made to all members of the FCS staff. In addition a considerable portion of Lobenstein's time was devoted to joint editorial review with Croft of all material prepared for inclusion in both the basinwide and Area I reports.

At the end of the period subarea report assignments were approximately 80 percent complete. Final review of Chapter II - Area Characteristics and Chapter III - Problems were finished with the exception of certain parts assigned to other agencies which had not yet been received. All material for Chapter IV - Program (Conservation Development and Use) was completed in rough draft form. Program measures for Chapter V - Measures Primarily for Flood Control were assembled and tabular summaries prepared. Approximately half of the narrative material for this Chapter V was finished in rough draft form.

An evaluation of the physical effects of the recommended program on runoff was made for sample watersheds by types of floods (snowmelt and rainfall) and narrative of procedural methods as results was prepared.

After a protracted period of discussion between participating agencies regarding methods and specific values to be used in range evaluation. Agreement was finally reached and estimates of the physical effects and monetary benefits expected to accrue from the land treatment program on forested and rangelands were developed and the evaluation sections completed in draft form.

At the request of the USDA Columbia Basin Field Committee and on a reimbursable basis, base maps were drafted for each of the subareas for which supplemental reports are being prepared.

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* Prepared for the first quarter to place subsequent report on the April 1 - October 1 bi-annual schedule.

Arkansas-Red-White

The limited amount of time spent on this project was devoted to the completion of narrative write-ups of the waterflow retardation program and program tables for the area above Pueblo.

At the request of the Corps of Engineers (Albuquerque office), Adams of our staff conducted representatives of that agency on a field inspection of the Manitou area as a means of answering questions raised by the Corps regarding the recommendations included in the Fountain River Flood Control Survey Report. Results of this meeting have been submitted in separate memorandum.

General

During this period Adams, Thurmond, and Murray were on detail assignments to R-4 for a total of approximately 16 man-weeks.

Review and revision of farm forestry phases of a number of reports prepared by the SCS, Lincoln office, covering small watersheds in central Kansas and Nebraska was completed.

QUARTERLY REPORT

FOREST INFLUENCES AND FLOOD CONTROL SURVEYS

April 1, 1953

FLOOD CONTROL SURVEYS

by Donald E. Whelan

STATUS OF FLOOD CONTROL SURVEY REPORTS

Connecticut River.—In Secretary's Office.

Merrimack River.—Step 2 draft in review.

Salt River.—Step 8 draft submitted to Washington Office.

Allegheny River, Upper Susquehanna River, and Monongahela River.—No progress.

NE-NYIAC—Resources Survey.—Basin reports in process.

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In the last quarterly report the Forest Influences Division of the Rocky Mountain Forest and Range Experiment Station discussed their efforts to establish the significance of grazing treatments on infiltration.

The Division has made two approaches to the problem: one, comparison of f_c values; and second, statistical analysis of related variables. Dissatisfaction was implied in both approaches since f_c in some cases was higher for poor grazing treatments than for good grazing treatments, and since the statistical analysis indicated "that the poorer the vegetation, the higher the infiltration rate (f_c)."

In hydrology it seems that there is always some inherent difficulty in obtaining one variable that can be used as a basis of comparison for all conditions. In comparing storms for instance, many attempts have been made to relate the maximum rainfall intensity for periods varying from 5 minutes to 24 hours to the peak flood flow. There is usually some degree of correlation with the results generally improved as the drainage area considered becomes smaller. Some of the other variables that make this comparison difficult are as follows: total storm rainfall; the regimen of distribution of rainfall intensities throughout the storm period; soil-moisture content at the beginning of the storm; values of detention and retention storage and percolation rate of the soil horizons; soil-cover complexes; and the components of the peak flood flow--surface, subsurface, and ground-water runoff.

In comparing grazing treatments on the same soil-cover complex it seems important to me to remember that our direct objective is what will be the variation in the volume and time distribution of surface runoff between grazing treatments for a range of storms. One question is that, if f_c for several grazing treatments is applied to the storm rainfall, will the comparison of the respective volumes of surface runoff be satisfactory, especially in view of the variables discussed in the above paragraph. Another one of our inherent difficulties is that surface runoff is computed as a residual--the difference in rates of precipitation and infiltration against time--so that it is not a direct function of infiltration rate.

The question was raised what does f_c mean physically. In a soil moisture study on the Allegheny watershed, Trimble took two undisturbed soil samples of the "C" horizon in nearly 300 plots covering a wide range of forest and open land soil-cover complexes. He found that the detention and retention storage and percolation rate for the "C" horizon did not vary significantly by cover complexes. It could be interpreted from these data that the f_c of any soil-cover complex would be identical with percolation rate of the "C" horizon or parent material for that basic soil group. The f_c could be expected, however, to be higher than the percolation rate to the extent of the rate of lateral or subsurface flow.

We have found in our area that usually about 85% of the roots are located in the first 18 inches of the soil profile. If there is significant root activity in the "C" horizon or parent material, it could be expected that the f_c would be correspondingly higher.

I notice that the depth of soil moisture penetration is also measured according to Station Paper No. 9 "Design and Operation of Rocky Mountain Infiltrometer" by E. J. Dortignac. The validity of the above discussion can be determined by measuring the lateral and vertical penetration of the simulated rainfall into the mass of the soil profile. By taking undisturbed soil samples by horizons outside the infiltrometer area before the run and after the run within the lateral area of penetration, the disposition of the rainfall in the soil mass can then be approximated.

By routing the rainfall through the soil horizons with their detention and retention storage and percolation rate values, it should be possible to reproduce the infiltration curve as obtained from the infiltrometer run. From such a study one would gain a real understanding of what f_c represents.

In our work we have found that land-use management has its greatest influence on the surface soil horizon and that it decreases as the soil depth increases. The increase in the soil detention and retention storage and percolation rate of the upper soil horizons permit more water to be held in temporary storage during rainfall bursts so that there is greater opportunity to utilize the storage in the parent material and for water to flow laterally. We found that by routing rainfall for a specific storm through the soil profile for each soil-cover complex we could obtain the respective total amount of infiltrated water in each case. We then determined what constant infiltration rate applied to the storm rainfall would produce the volume of surface runoff for each soil-cover complex--the difference between the total storm rainfall and the total infiltrated water. If this process is followed through for a range of grazing treatments, the resulting equivalent infiltration rate should form an adequate basis for comparing effectiveness of grazing treatments on infiltration.

FOREST INFLUENCES

DELAWARE BASIN RESEARCH CENTER
by the Delaware Basin Staff

Rain and Snow

For the third straight year, a high level of precipitation is being recorded at Dilldown Watershed. It now appears likely that our original estimate of normal precipitation for the watershed was too low and that the high yearly totals for the past two years were not as much above normal as we previously believed.

Our original estimate was taken from a small scale isohyetal map showing the average rainfall for this part of the State. Published precipitation records for nearby stations are incomplete and cannot be used for comparison with any confidence. It is quite likely that the particular topography in the vicinity of Dilldown causes a local rainfall pattern different than that for the Pocono Plateau as a whole.

The possibility is strengthened by comparison of rainfall rates between the Dilldown Watershed and the Pocono Experimental Forest. Although the two areas are of practically the same elevation and the airline distance between them is only 16 miles, annual rainfall at the Pocono Experimental Forest has been consistently about 20 percent less than that at the Dilldown Watershed for the period of measurement.

The following tabulation compares the records for the two areas:

Precipitation - Inches
Hydrologic Year

	1949-50	1950-51	1951-52	1952-53
Five-month totals Oct. 1 to Feb. 28				
Dilldown	17.88	28.33	26.90	27.88
Pocono	14.67	23.83	20.68	21.26
Yearly totals Oct. 1 to Sept. 30				
Dilldown	45.08	59.94	75.88	--
Pocono	37.31	50.21	59.39	--

Snowfall and snow storage were very low at the Dilldown Watershed during the past winter. The deepest snowfall was about eight inches early in January. Most of this melted in the following two weeks and was entirely gone by the beginning of February. Two other measurable snowfalls, one each in December and February, lasted only a few days.

The open condition of the winter was also reflected in the slight amount of soil freezing as compared to frost depths of other winters. Frost measurements continued from the middle of December to the end of March. At no measurement was over four inches of frost found and this was granular frost. No concrete frost entered the minersal soil throughout the winter.

Temperature

Several years ago we noticed the minimum thermometers at our weather stations generally were registering a lower temperature for the current reading than were the maximum thermometers. If both thermometers were exact, they would register the same temperature at the time of measurement.

Since then, the weather observers at the Delaware-Lehigh and Pocono Experimental Forests have been recording the readings of both thermometers taken simultaneously.

Recent analysis shows that the minimum thermometer is almost invariably lower than the maximum thermometer and that the differences grow progressively larger with time, becoming as great as three degrees.

A mercurial thermometer such as the maximum thermometer is considered much more exact than a minimum thermometer which contains alcohol. The alcohol is a highly volatile fluid; in time part of the main column will distill off and condense at the top of the tube. As the minimum thermometer is never exposed in an upright position, the main column gradually decreases in size and thereby registers gradually decreasing readings.

The effect of this condition is the registering of minimum temperatures lower than actual and may give a misleading picture of the climate in the vicinity of the weather station.

Fortunately, we have the simultaneous readings and are able to determine correction factors to apply to our recorded minimum temperatures. However, considerable time was spent during the quarter making these corrections in preparation for publication of weather data at the Delaware-Lehigh Experimental Forest.

It is believed this job may be eliminated in the future by a periodic rotation of minimum thermometers. The accuracy of a minimum thermometer may be restored by joining the entrapped fluid to the main column. This is a delicate procedure in which hot water is used carefully to drive up the main column until it touches the entrapped fluid. The thermometer is then hung in an upright position for a number of days to allow the fluid to drain off the sides of the capillary tube into the main column.

Following this procedure, the minimum thermometer will read very close to the maximum thermometer and no correction will be necessary. We shall continue to record both temperatures as a check. When the differences begin to average more than 0.5 degree, the thermometer will be removed for adjustment and a recently-adjusted thermometer will be installed.

Meetings

Don Whelan (Flood Control) and Bethlahmy attended the Tenth Annual Eastern Snow Conference. Easterners are becoming increasingly aware of the importance of water, snow, and ice. Since the end of the war, the number of representatives attending the conferences has increased annually. Generally, both government and industry are well represented. Of special interest this year was the large number of Canadian representatives.

In our last quarterly report, we reported on the damage done in the City of Bethlehem watershed. Since that time, Reigner and Bethlahmy, with Frantz (of INCODEL), inspected the watershed together with the Mayor and his council. Remedial measures were outlined. Since the problem has now attracted the attention of the chief city officials, perhaps corrective measures will soon be instituted.

MOUNTAIN STATE RESEARCH CENTER

by the Staff

GENERAL

Calibration of the five watersheds on the Fernow Experimental Forest is continuing. Two growing periods and one dormant period have passed since the initiation of the study. Aside from maintaining these calibrations, our main efforts during the past two years have been concentrated on studies of road erosion. These studies will be intensified during the coming year.

SKID ROAD EROSION

We have been making a study of the factors involved in skid road erosion and attempting to define remedial or alleviating measures. The first results from these studies have been presented in two papers: "Skid Road Erosion Can Be Reduced" Weitzman and Trimble, Journal Soil and Water Conservation, July 1952; and "Soil Erosion on Skid Roads" Trimble and Weitzman, paper presented at the annual national meeting of the Soil Science Society of America in Cincinnati, Ohio, November 1952.

KRILIUM

Work has been started to determine the effect of Krilium in controlling post-logging skid road erosion. The study is being made on four sections of skid road; two with grades of 27 percent, and two with grades of 36 to 42 percent. One section in each grade class has been treated; the duplicate sections are controls. Each section is 120 feet long and separated from the rest of the road by water bars. All sections were subjected to the same heavy usage during skidding.

Krilium was applied at the rate of approximately 400 pounds per acre. It was applied in mixture with inert clay in the ratio of 3 parts clay to 1 part Krilium. Frequent erosion measurements will be made to determine soil loss from the sections. In addition, detailed observations will be made of natural revegetation on each section.

SKID ROAD REVEGETATION STUDY

It is known that vegetation reduces erosion. The purpose of this study is to determine if a vegetative cover can be established on skid roads through the use of chaff from local sources. The chaff contains wheat, oat, and weed seeds.

Specifically the objectives are:

1. To determine if the seeds in the chaff will germinate and thrive on bulldozed and compacted skid roads under each of the following conditions:

    A. Broadcast seeding--no mechanical disturbance--no fertilizer or lime.

    B. Broadcast seeding--mechanical disturbance--no fertilizer or lime.

    C. Broadcast seeding--mechanical disturbance--fertilizer and lime.

    D. Broadcast seeding--no mechanical disturbance--fertilizer and lime.

    E. No treatment--control.

2. To determine the differences between treatments and to evaluate which treatments result in successful vegetation.

Soils data will be collected from the test area before treatment. Seeding will be done during March 1953.

The experimental design will take the form of a latin square.

TRUCK ROAD EROSION

On the Monongahela National Forest, a set of standards for constructing and maintaining logging roads have recently been developed. These standards are based on the best information available in respect to width, grade, and maintenance. However, there is no evidence to show that these roads are or are not adequate to protect soil and water values. A study is being initiated on the Fernow Experimental Forest where two roads have been built to these standards, to test their effectiveness in erosion control.

The specific objectives of this study are:

1. Relate the rate of erosion on a truck road built to Monongahela standards to:

    A. Grade

    B. Distance between road surface drainage structures. Adjustments in these standards can be made in accordance with the findings of this study.

2. Determine the effectiveness of after-logging treatment in reducing erosion and relate this reduction to:

   A. Grade

   B. Distance between surface drainage outlets.

Two types of treatment will be tested on these roads after the logging operation is over and the roads are put to bed:

1. Seeding to Lespedeza sericea.

2. Brushing with hardwood tops and limbs from the logging operation.

SEDIMENTATION STUDY

In connection with the erosion study on truck roads, a sedimentation study is being made on the stream draining the hollow up which one of these truck roads was built. The purpose of this study is to evaluate and demonstrate the effect of building a road to Monongahela standards up a typical forested watershed. It will, to some extent, serve as a partial test of these Monongahela road standards.

Water samples were collected from the test watershed and a control (undisturbed) watershed before and during construction and are being collected after construction. Sampling procedure is designed to sample all water level stages occurring in any period; i.e. before, during, and after construction, and during and after logging. In addition to sampling by stages intense sampling is done during and immediately after heavy rains.

EFFECT OF A FOREST CANOPY ON GROUND RAINFALL INTENSITIES

A study to determine the effect of a fully stocked hardwood forest canopy on ground rainfall intensities, and incidentally, throughfall, has been completed. A manuscript entitled "The Effect of a Hardwood Forest Canopy on Rainfall Intensities" has been written and is now being processed for submission to a suitable periodical.

This study was begun in the summer of 1951 and carried well into the summer of 1952. It was discontinued during the spring and fall when the trees were in a stage of transformation from bare to leaf and vice versa. Five recording rain gages were placed at random in an area of 50-year old hardwoods. Elevation, aspect, and slope position were similar for all gages. The control consisted of a recording gage in a one-half acre cleared plot within 150 yards of any canopy gage and similarly located with respect to elevation, aspect, and slope position.

Three comparisons were made between the measurements recorded at the open and canopy gages:

(1) Maximum 5-minute intensities

(2) Maximum 15-minute intensities

(3) Throughfall.

The results of these comparisons were computed separately for summer and winter conditions and are summarized below:

1. The differences in intensities and throughfall between the open and the average of the canopy gages were highly significant at the one percent level in all cases.

2. Linear regression equations were determined to enable estimation of intensities and throughfall under a canopy from measurement of rainfall in the open. They are as follows:

<u>Summer</u>

Max. 5-minute intensities – $\hat{Y} = 0.97584X - 0.07728$

Max. 15-minute intensities – $\hat{Y} = 0.94766X - 0.06106$

Throughfall – $\hat{Y} = 0.80918X - 0.01636$

<u>Winter</u>

Max. 5-minute intensities – $\hat{Y} = 0.85238X - 0.01184$

Max. 15-minute intensities – $\hat{Y} = 0.80715X + 0.00674$

Throughfall – $\hat{Y} = 0.78911X - 0.00618$

Examination of these equations leads to several important observations:

A. High intensity rainfall is but little reduced by the tree canopy in either summer or winter. However, these high intensities are reduced more by the bare crown in winter than by the leafy crown in summer. For example, the winter canopy reduces a 5-minute maximum open intensity of 3.00 inches per hour by .45 of an inch or to 2.55 inches. The summer canopy reduces this same open intensity only to 2.85 inches. This difference is significant.

B. The lower the rainfall intensity, either in summer or winter, the greater is the relative reduction by canopy.

C. The effect of canopy in reducing given intensities increases slightly with an increase in the length of the period of measurement--at least as between 5 minutes and 15 minutes. As illustration, given a summer intensity of 3.00 inches per hour for a 5-minute period, the reduction by canopy is .15 of an inch. Given the same intensity for a 15-minute period the reduction is .22 of an inch. The same trend holds true for winter conditions.

D. Throughfall is reduced by canopy interception approximately the same amount in both summer and winter.

E. For throughfall, as for most intensities, the relative effect of canopy varies inversely with the size of "X".

F. Coefficients of variation for canopy gage averages indicate greater variation beneath a summer canopy than beneath a winter canopy for both intensities and throughfall. The coefficients of variation also indicate that variations tend to be greater for storms of low total precipitation than for large storms.

G. In the case of every canopy gage, both summer and winter, individual gage averages for the period were less than the open average and closer to the canopy average than to the open average.

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION

Forest Influences
Quarterly Progress Report, January 1 - March 31, 1953

General

Since 1949 the flood-control division has been covering the waterfront in the Pacific Northwest. Members of the division are sincerely concerned with more than flood control. They have done some basic thinking about watershed-management research and, through the "Advance Studies" device, have made some good beginnings in the field. Center of attention has been the H. J. Andrews Experimental Forest (formerly Blue River Experimental Forest) where three trapezoidal flumes and two intensity rain gages have been installed. Here we have a good beginning for a small-watershed study in old-growth Douglas-fir with the first year of calibration well along. The working plan, now virtually completed, envisions a long-term investigation of water yields and erosion in relation to timber cutting. Other and more tentative plans have been made for small-watershed research in eastern Washington near Wenatchee and in the Blue Mountains of eastern Oregon.

Some other small studies have been completed and reports made, including Hale's soil-freezing study, Sartz' erosion observations on the Portland burn, and suspended sediment sampling in various streams throughout the region. Others have been started but temporarily suspended because of shortage of personnel.

Personnel of the flood-surveys division have also been frequently called upon to give help in various ways to several land management agencies. They have assisted the Engineering Division (Forest Service) in drawing up specifications for soil mapping to determine drainage control; helped the Bureau of Land Management develop study plans for mustard seeding on a large burned area in Oregon; and furnished help in designing a water yield study undertaken jointly by the City of Tacoma and the Geological Survey in the Green River drainage. Also, inspection of watershed conditions have been undertaken at the request of four national forests, the U. S. Navy, and the City of Tacoma.

These activities have all been undertaken as "extra-curricular" functions, but with the hope that a forest influences division would be established to carry them on. That hope may become a reality soon. Strong support for watershed research has developed in the Pacific Northwest because of the sudden realization that water problems are with us and are speedily growing more complex.

Problem Analysis

During the first quarter of 1953 Dunford has been devoting considerable time to a regional analysis of these water problems. The object is to study the whole array, single out the ones that can and should be attacked by research, and to outline the plan of investigation.

A major problem in the region is erosion resulting from bad land-use practice. The result is decreased productivity, higher flood peaks, and lowered water quality. Adequacy and timing of water yields appear to be secondary in importance. Three basic causes of erosion are, in order of importance:

1. Roads (including logging access roads).
2. Logging (harvesting activities including skid trails).
3. Grazing.
4. Fire.

First order of business for watershed research is to provide guides for improved land use. To reach that objective in the relatively near future it would seem that some of our attention should be given to the technique of investigation employing controlled experience. There is a wealth of experience in the Pacific Northwest to draw upon, but we need an orderly assembly of these examples for all classes of circumstances. For instance, we have the question of where and when logging with tractors can be permitted. Enough tractor logging has been done so that results can be observed under a variety of slopes, exposures, soils, and vegetative types. Careful cataloging of the results by these categories should provide some well-defined principles of tractor operation.

Municipal Watersheds

Region 6 of the Forest Service is responsible in total or in part for the watersheds serving 112 communities. The population involved represents 42 percent of the total for Oregon and 36 percent for Washington. In most cases these watersheds contain large volumes of highly valuable old-growth timber. During past years the Forest Service has been reluctant to disturb many of these areas because of the possibility of creating real damage to domestic water supplies. One notable exception is the Cedar River watershed which has been logged without damage to water supply because of careful supervision by city forester and the unusual porosity of the soil. Other watersheds having different and probably less stable soils are going to require extra precautions dictated by watershed management requirements. Not knowing what these are, the Forest Service has chosen to postpone cutting and rely on fire protection as the only measure of management.

Recently, however, two developments have forced more positive management program on municipal watersheds. One of these is the growing clamor for release of "bottled up" old-growth timber, and the other is a sharply increased rate of mortality from an epidemic attack of Douglas-fir bark beetles.

Mary's Peak Watershed.--A case in point is a 5,000-acre watershed in the coast range of Oregon which supplies water for the City of Corvallis. Beetle attack has been rampant and losses of timber running into billions of board feet are imminent. The Siuslaw National Forest is beginning a series of sales to salvage the bug-killed material in spite of the misgivings of local people whose water supply will be affected.

We have been asked to contribute from our research experience, but, unfortunately, we are not in very good position to help. We have reviewed the sales contract and made suggestions to safeguard road and skidtrail erosion. Very little opportunity is provided for sound quantitative research because disturbance of part of the watershed will begin soon. However, we have started some cooperative work with the City of Corvallis and Oregon State College to evaluate a few of the effects of logging in the early stages in order to develop better methods as the salvage operation proceeds.

One activity has been started in cooperation with the Corvallis Water Bureau to determine the relative turbidity load before and after logging. Sediment samples are not available for the past, but the city has a record of the number of cleanings per day necessary to keep their filters functioning properly. The number of cleanings is roughly correlated with fluctuations in sediment load of the stream which is, in turn, associated with rainfall. At our suggestion the Bureau is now taking sediment samples which will give pre-disturbance data for a few months at least. One hope is that a relationship may be established with frequency of filter cleanings and perhaps daily rainfall to provide a basis for estimating the quantity of sediment transported in the past.

We have also been developing plans for cooperative soils studies with Dr. C. T. Youngberg of the Oregon State College Department of Soils. Tentative agreement has been reached whereby Youngberg will make a detailed classification of the watershed soils and direct laboratory determinations of erosion index and physical changes resulting from logging. The results of these studies will not be available in time to assist in the early sales, but may provide guides for those planned a year or two hence.

We are hoping that the erosion index determination worked out in conjunction with recognizable surface features will give some leads as to potential trouble spots. In a recent trip

through the watershed, we made an elementary observation that may yield fruitful results if followed out by more study. Our route of travel was a simple fire trail with no rock surfacing. Most of the roadbed appeared stable but, in one section, wheel tracks dug deep and surface runoff was definitely increased. On nearby cut banks, erosion pedestalling was very prominent, whereas it was entirely absent where the road surface appeared more stable. Looking at the undisturbed forest floor adjacent to the road, we observed the same condition in soil uprooted by windfalls and other natural openings normally found in a virgin area. Further analysis of these soils and continued observation under use may prove that such simple evidence may be an important clue to their reaction to logging disturbance.

Bull Run Watershed.--Residents of Portland, Oregon are exceptionally proud of "their Bull Run watershed" and the pure (3 ppm) water it provides for household use. But Bull Run belongs to all the people of the United States and contains some other values besides water. Some folks would like to put the other values to good use. Bark beetles have not hastened the issue here as they have in the Mary's Peak watershed, but nevertheless it is a problem the Mt. Hood National Forest must soon face. They need answers and are not going to be too much interested in the negative kind. It will be the responsibility of research to point out methods by which watershed management can be undertaken.

In anticipation of future pressures for cutting, the Mt. Hood Forest has developed a special plan of management for the watershed. In its first stages it will involve merely development of fire trails and salvage of snags to intensify protection. Again, we have been asked to help guide these efforts. Our plans, while they can be only tentative now, call for more than that. We hope eventually, by cooperative effort of all concerned, to make the Bull Run drainage a demonstration of the best watershed-management practices devised to date. Our results from the current logging program at the Andrews Experimental Forest will very likely prove valuable in this effort.

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REPORTS
Quarterly - FI

April 1, 1953

QUARTERLY REPORT
January 1 to March 31, 1953

Forest Influences Division
Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

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THE WATERSHED ASPECTS OF "BUG-KILLED" SPRUCE[1/]

INTRODUCTION

Recently much public interest, and no little speculation, has been concerned with the effects of "bug-killed" spruce on water yields and on watershed conditions.

In western Colorado, Engelmann spruce and lodgepole pine stands have been infested by the spruce beetle (Dendroctonus engelmanni). Beginning in 1941, as a result of wind destruction of the spruce on the White River Plateau in western Colorado, the normal endemic beetle infestation became an epidemic. Large areas of spruce were successively infested and killed between 1942 and 1945. Smaller areas suffered losses during 1946 and 1947. Not only were large trees damaged, but also small trees and lodgepole pine were attacked. Only alpine fir and small spruce saplings escaped the onslaught of the beetles

The epidemic spread northeastward across the White River Plateau toward the spruce forests of the Routt National Forest. Sporadic outbreaks occurred southward in the vicinity of Glenwood Springs, Basalt, and on the Grand Mesa. But none were as devastating as the outbreak which occurred on the White River Plateau where 95 to 100 percent of the trees of the timberlands were killed by the beetles.

Such large areas of dead trees must have some measurable effect on the watersheds in which they occur. Since the White River Plateau was the location of the original onslaught by the beetles, it should now provide information as to the effects of dead spruce on watershed conditions. The White River Plateau is drained by the White River which rises in the Plateau itself, and flows westward to join the Green River in Utah.

Any effects which large areas of bug-killed spruce would have on a watershed should be reflected in the stream flow of the stream draining the area infested. Stream flow is the net result of the interaction of climate, plants, and soil on a particular drainage area. It is the mirror which reflects the amount of precipitation, temperature, evaporation, transpiration, and the use of the land by man. It is the yardstick of watershed behavior (1).

1/ Material prepared for Rocky Mountain Section of Society of American Foresters, and as source information for Region 2.

The climate from year to year is generally accredited with the abundance or scarcity of water supplies as measured by the stream flow of western streams. But this stream flow can be altered in one direction or the other, depending upon the husbandry man applies to the watershed lands. In his use of the vegetation, man may alter the quantity and quality of stream flow by changing the crops grown, by cultivation, by grazing, by changing the water use of the plants.

To ascertain the watershed effects of the areas of spruce killed by the beetles, it is necessary to isolate any effects of climate. Confining our analysis to White River, the drainage area of which had the severest attack by beetles, requires that comparisons be made with at least one other drainage which has not suffered attacks by beetles. Fortunately, this is possible.

The stream flow of the White River, which drains the bulk of the White River Plateau, has been gaged at Meeker, Colorado, since 1934 (2,3,4). The watershed area above the gaging station is 762 square miles. The average annual flow from 1934 to 1952 is 427,620 acre-feet, or 10.52 inches over the watershed. Elevations range from 6,500 to 11,500 feet. The lower portion of the watershed is covered with sagebrush and aspen groves, while in the upper portion, three-fourths is open mountain-grassland parks and the remainder is lodgepole pine, Engelmann spruce, and alpine fir timberlands. These timberlands occur on the steeply sloping ridges and in isolated groves in the mountain parks.

On the watershed as a whole the timberlands occupy 17.5 percent of the area, or 133 square miles. It is on this area that from 95 to 100 percent of the trees have been killed by the spruce beetle.2/

Some 60 airline miles to the northeast, near Steamboat Springs, Colorado, is the watershed of the Elk River, a drainage of 206 square miles. Since 1937 the stream flow of this stream has been measured at Clark, Colorado (2,3,4). The average annual flow from 1937 to 1952 is 240,840 acre-feet, or 21.92 inche over the watershed. Elevations range from 7,500 to 12,000 feet. The bulk of the area consists of lodgepole pine, Engelmann spruce, and alpine fir timberlands. Some alpine occurs above 11,500 feet elevation on the high mountain peaks which form the Continental Divide.

So far, the Elk River watershed has been free of the spruce-beetle infestation

Any variation from year to year in the stream flow of the Elk River can be attributed to climate; mostly in the form of winter precipitation. Any mass change in climate from year to year that would affect the Elk River watershed would also affect the White River watershed in like proportion. The climatic changes would be reflected in both annual and seasonal stream flow of the two streams. For example, the correlation between the water content of the snow as of April 1 on the Elk River watershed and that on the drainage area of the White River is high (0.695 for the years 1936-1952) (5). The water content of the snow on April 1 on the White River watershed is associated, 99 times out of 100, with the water content of the snow on the Elk River drainage.

2/ Local citation. Of the 762 square miles, 229 are outside the White River National Forest boundary. On the remaining 533 square miles, 25 percent are timberlands which suffered the attack of the spruce beetles.

Any effect which the bug-killed spruce will have on the stream flow of White River must come from two fundamental causes: (1) reduced interception of snow and rain by the dead trees; and (2) reduced transpiration (water use) by the trees. Beetles kill the trees in 1 year and here transpiration stops, but it is not until the following year that the needles and small twigs of the spruce drop off and interception of snow and rain is reduced. The successive waves of beetle attacks during 1943 to 1945 caused larger and larger areas of trees to drop their needles and to become permanently defoliated. Thus, it was not until the summer of 1946 when large areas of spruce on the White River Plateau were completely defoliated, and although transpiration had stopped, the full effect of reduced interception was not apparent until the snows came in the spring of 1947.

Annual stream flow is customarily summarized by water years; that is, from October 1 of 1 year to September 30 of the next. The 1947 water year includes the period from October 1, 1946, to September 30, 1947.

ANALYSIS OF EFFECTS

Variations in stream flow from year to year of a particular stream will occur above and below a long-time average. If permanent changes have occurred on a watershed to alter the stream flow, then the yearly variations will continue either above or below the long-time average.

Such an analysis was tried for the Elk and White rivers. The annual stream flow was expressed in inches over the watershed because of the difference in the size of the two watersheds. The average discharge for Elk River for the period 1937-46 was 21.2 inches, while for White River during the period 1934-46 it was 9.67 inches. The annual deviations from these averages were plotted for all years of record (fig. 1).

Prior to 1947 the annual variations in stream flow of White River fluctuated above and below the 1934-46 average. Beginning with 1947, the annual variations were above this average. This indicates some permanent change on the watershed; a change which may be attributed to climate, beetle infestation, or other causes.

On the other hand, the annual variations in stream flow for Elk River continued to fluctuate above and below the average for the period 1937-46. This indicates no permanent change on the watershed; merely the effect of the expected annual variations of climate on stream flow.

Has the change in stream flow of the White River since the 1947 water year been due to the weather or to the effects of the beetle-killed spruce?

Analysis of total annual flow

To answer this question, a comparison was made between the annual stream flow of Elk and White rivers. These data are summarized in table 1, page 4. Gradual defoliation of large areas of spruce had become so extensive by

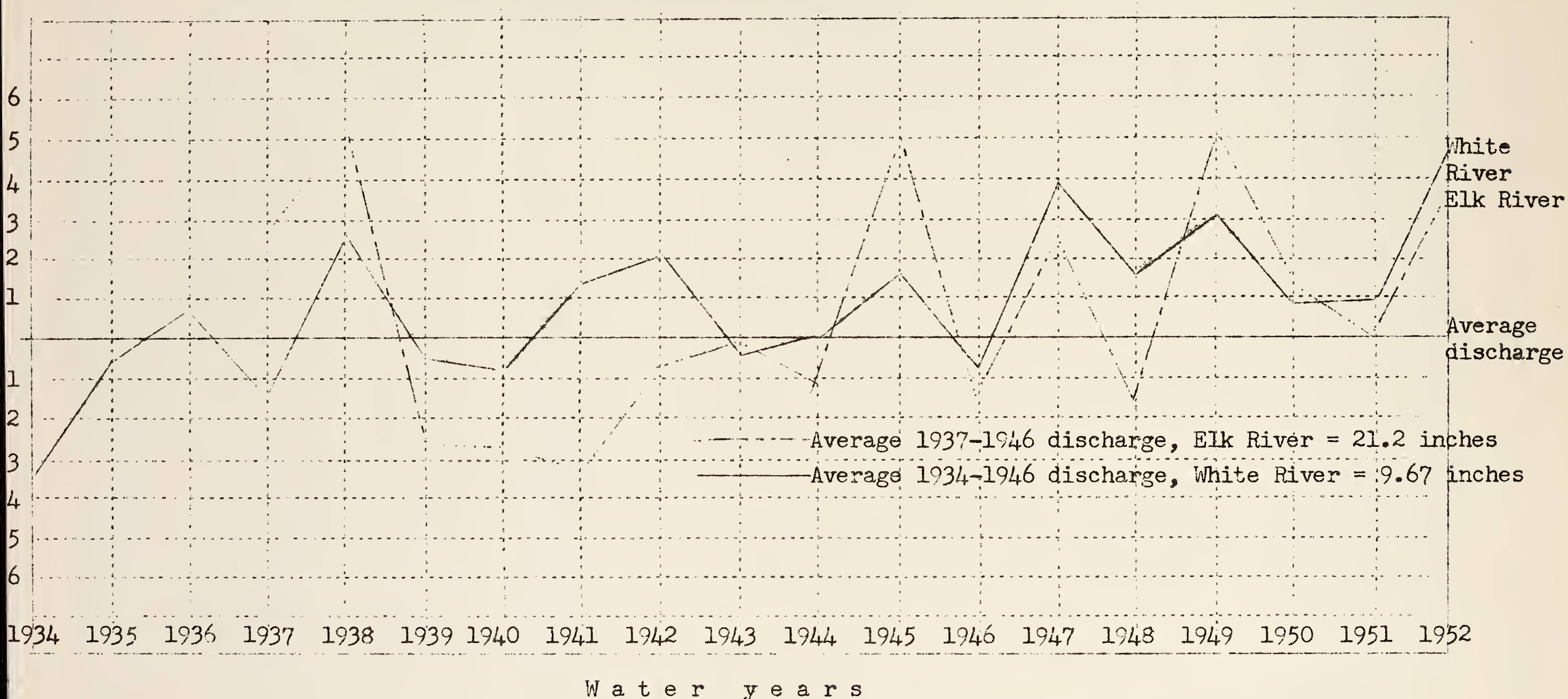

Figure 1.—Deviations in annual stream flow for Elk and White rivers for water years, 1934 - 1952.

the summer of 1946, that the reduced interception of snow showed its effect beginning with the water year 1947.3/

Table 1.--Comparison of the total annual stream flow of Elk and White Rivers for the period 1937-1952.

Before defoliation			After defoliation		
Water year	Stream flow Elk	Stream flow White	Water year	Stream flow Elk	Stream flow White
	inches	inches		inches	inches
1937	23.79	8.11	1947	23.76	13.62
1938	26.21	12.19	1948	19.43	11.30
1939	18.48	9.16	1949	26.54	12.86
1940	18.39	8.86	1950	22.60	10.56
1941	17.82	11.06	1951	21.21	10.83
1942	20.38	11.72	1952	25.15	14.91
1943	21.09	9.28			
1944	19.79	9.79			
1945	26.34	11.34			
1946	19.69	8.94			
Means	21.20	10.05		23.11	12.35

Characteristics of White River means (inches):

	Before		After
Difference due to climate and beetles		2.30	
Means adjusted for climatic changes	10.29±.44		12.11±.57
Difference due to beetle infestation		1.82±.72	
Error of the adjusted means for 95% certainty	±1.00		±1.47
Error of difference due to beetles for 95% "		±1.53	
Range of difference due to beetles for 95% "		.29-3.35	

Both streams showed an increase in stream flow beginning with 1947 as is indicated by their averages. However, as indicated previously, the changes in stream flow of Elk River are chance variations in climate, not, as in the case of White River, chance variations in climate plus a beetle infestation.

Using the total annual stream flow of Elk River as a net expression of mass changes in climate, it is possible to adjust the total annual stream flow of White River, before and after defoliation, to similar changes in climate with any remaining differences be·´· the expression of the effects of dead spruce.

The measured mean values for the stream flow of White River before and after defoliation of the spruce show an increase of 2.30 inches for the period 1947-52. This increase includes both the effect of climatic change and beetle infestation. When the mean values of White River are adjusted to the chance climatic variations occurring on Elk River, the difference in the mean annual stream flow of White River is reduced to 1.82 ± .72 inches.

3/ This analysis, as well as the three which follow, employs the analysis of covariance. The methodology of covariance is described in Snedecor (6) and illustrated in part by Wilm (7).

The statistical analysis showed that in only three times out of 100 would the increased flow have been due to chance. We can, therefore, with considerable confidence attribute it to the beetle infestation.

Analysis of total spring flow

The total annual stream flow of the Elk and White Rivers may be divided into two periods. One period is during April, May, June, and July when the stream flow of both streams is characteristically high due to melting snows, and the other is a period from August to March when stream flow is low.

Again, using the water year 1947 as the beginning of watershed changes on White River, the total spring flow for April, May, June, and July amounts to 61 percent of th total annual flow before defoliation, and 66 percent after. For the Elk River, the total spring flow is 82 percent of the total annual flow for the period before 1947 and 86 percent after. Winter and sprin snows are therefore responsible for the bulk of the stream flow of the two streams. An analysis similar (6,7) to the one concerned with total annual stream flow of the two streams was made for the total spring flow. A summary of the data is found in table 2.

Table 2.--Comparison of the total flow for April, May, June, and July for Elk and White Rivers, for water years 1933-1952.

Before defoliation			After defoliation		
Water year	Stream flow: Elk	Stream flow: White	Water year	Stream flow: Elk	Stream flow: White
	inches	inches		inches	inches
1933	18.50	7.41	1947	20.03	9.32
1934	9.54	2.49	1948	16.32	7.11
1935	18.04	5.83	1949	23.10	8.73
1936	21.76	6.76	1950	19.39	6.44
1937	21.23	4.83	1951	18.11	6.84
1938	21.73	8.46	1952	22.29	10.27
1939	14.48	5.33			
1940	15.84	5.36			
1941	14.37	7.27			
1942	16.39	7.66			
1943	18.08	5.47			
1944	17.17	6.34			
1945	21.77	7.41			
1946	15.69	5.18			
Means	17.47	6.13		19.87	8.12

Characteristics of White River means (inches):

	Before		After
Difference due to climate and beetles		1.99	
Means adjusted for climatic changes	6.49±.33		7.76±.50
Difference due to beetle infestation		1.27±.59	
Error of the adjusted means for 95% certainty	±.70		±1.28
Error of difference due to beetles for 95% "		±1.24	
Range of difference due to beetles for 95% "		.03-2.51	

Both rivers showed an increase in total spring flow during the period 1947-1952. The measured increase in total spring flow of White River amounted to 1.99 inches after defoliation. When the mean values for White River are adjusted for the climatic variations as expressed by the stream flow of Elk River, the difference in total spring stream flow after defoliation is reduced to 1.27 ± .59 inches.

The statistical analysis showed that in only five times out of 100 would the increased flow have been due to chance. We can, therefore, with considerable certainty, attribute it to the beetle infestation. This means that, through the defoliation of the spruce trees, more snow reaches the ground, melts, and the water seeps through the soil to appear as stream flow.

Analysis of low flows

A comparison was also made of the low flows of Elk and White Rivers. These low flows were concerned with the total flow of both streams for the annual period August 1 to March 30. Any increase in the flow of White River during this period, after defoliation of the spruce, might be attributable to lowered transpirational draft as well as to more water moving through the soil.

In table 3 are summarized the total flows for the annual period, August through March, for Elk and White Rivers.

Table 3.--Comparison of total flows, August through March, of Elk and White Rivers for water years 1937-1952.

Before defoliation			After defoliation		
Water year	Stream flow: Elk	Stream flow: White	Water year	Stream flow: Elk	Stream flow: White
	inches	inches		inches	inches
1937	2.56	3.28	1947	3.73	4.30
1938	4.48	3.73	1948	3.11	4.19
1939	4.00	3.83	1949	3.44	4.13
1940	2.55	3.50	1950	3.12	4.12
1941	3.45	3.79	1951	3.10	3.99
1942	3.99	4.06	1952	2.86	4.64
1943	3.01	3.81			
1944	2.62	3.45			
1945	4.56	3.93			
1946	4.00	3.76			
Means	3.52	3.71		3.23	4.23

Characteristics of White River means (inches):

	Before		After
Difference due to climate and beetles		.52	
Means adjusted for climatic changes	3.68±.06		4.26±.08
Difference due to beetle infestation		.58±.10	
Error of the adjusted means for 95% certainty	±.14		±.21
Error of difference due to beetles for 95% "		±.22	
Range of difference due to beetles for 95% "		.36-.80	

In this instance the mean low flow of Elk River dropped after 1947 while that of White River increased. This latter increase amounted to 0.52 inch, and when the mean values of White River were adjusted to climatic variations of Elk River, this difference increased to .58 ± .10 inch.

The statistical analysis showed that in only one time out of 100 would the increased flow have been due to chance. We can, therefore, with considerable certainty attribute it to the beetle infestation. This increase may be coupled with the lowered demand for water through the death of the spruce. Likewise, it may be altered by increased growth of vegetation in the form of spruce reproduction and herbaceous vegetation.

Analysis of the water content of snow

Another comparison was made between the water content of snow on April 1 and the total annual flow of White River. Two snow courses have been run since 1936 and they provide indices of the yearly fluctuations of climate, particularly winter precipitation. It was pointed out earlier that from 61 to 66 percent of the annual stream flow of White River comes from snow.

The Burro Mountain Snow Course (#35) is located 13 miles south of Buford in an open-park tributary to the south fork of the White River. Its elevation is 9,000 feet. The average water content of the snow pack on April 1 is 18.6 inches for the years 1936-1952 (5).

The Rio Blanco Snow Course (#36) is located 6 miles northwest of Trapper's Lake at an elevation of 8,500 feet. It is in an open-park tributary to the north fork of the White River. The average water content of the snow pack on April 1 is 16.1 inches for the years 1936-1952 (5).

Both the snow courses are in open parks and have not been influenced by the beetle infestation. Any mass changes in winter climate on the White River watershed would be reflected in snow measurements of the two courses. In table 4 is summarized the average water content on April 1 of the two courses and the total annual stream flow of White River.

Both the water content of the snow on April 1 and mean annual stream flow of White River have increased since 1947. The measured increase in average stream flow is 2.28 inches and when it is adjusted for annual variations in water content of the snow pack, it is reduced to 1.30 ± .48 inches.

The statistical analysis showed that in only four times out of 100 would the increased flow have been due to chance. We can, therefore, with considerable certainty, attribute it to the beetle infestation. Less snow is intercepted by the dead trees than formerly by the live ones so that more of the water in the snow pack appears as stream flow. Likewise, it may later be altered by increased interception of the snow by spruce reproduction.

Table 4.--Comparison of the water content of snow on April 1 and total annual flow of White River for the years 1936-1952.

Before defoliation			After defoliation		
Water	Stream flow		Water	Stream flow	
year	Elk	White	year	Elk	White
	inches	inches		inches	inches
1936	20.6	10.30	1947	18.5	13.62
1937	15.2	8.11	1948	19.2	11.30
1938	20.8	12.19	1949	22.9	12.86
1939	17.6	9.16	1950	15.7	10.56
1940	13.5	8.86	1951	15.0	10.83
1941	16.6	11.06	1952	26.3	14.91
1942	18.6	11.72			
1943	14.5	9.28			
1944	13.2	9.79			
1945	20.0	11.34			
1946	12.7	8.94			
Means	16.66	10.07		19.6	12.35

Characteristics of White River means (inches):

	Before		After
Difference due to climate and beetles		2.28	
Means adjusted for climatic change	10.56±.28		11.86± .38
Difference due to beetle infestation		1.30±.48	
Error of the adjusted means for 95% certainty	±.63		±.99
Error of difference due to beetles for 95% "		±1.01	
Range of difference due to beetles for 95% "		.29-2.31	

DISCUSSION

Each of the four analyses show a substantial increase in the mean flow of the White River. This increase is attributed to the beetle infestation of lodgepole pine and spruce on the White River Plateau.

Ninety-five percent of the time, the increase in the annual total stream flow of the White River will amount to 1.82±1.53 inches as a result of the beetle infestation. When broken down into spring flow and summer-winter flows, the increases amount to:

Spring flow (April, May, June, July) . . .	1.27 ± 1.24	inches
Summer-winter flows	.58 ± .22	"
Total (check only)	1.85 ± 1.46	"

Most of the increase comes from snow stored overwinter on the watershed and from storms occurring after April 1. The water content of the snow on April 1 gives a good index to stream flow (see table 4). Ninety-five percent of the time the increase in the annual total stream flow of the White River will amount to 1.30 ± 1.01 inches from the water content of the snow pack on April 1.

A comparison of the expected ranges in the increase of total annual stream flow of White River reveals the importance of reduced interception of snow.

	Range
From table 1	.29 - 3.35 inches
From table 4	.29 - 2.31 inches

The least detectible increase in annual stream flow due to the beetle infestation is the same in each case. An increase up to 2.31 inches may be attributed to the water content of the snow on April 1, while an increase up to 3.35 inches may be attributed to additional snows or rains after April 1

So far, the discussion has been concerned with the increases in stream flow of White River as measured at the gaging station and distributed uniformly over the 762-square-mile watershed. But only 133 square miles were affected by the beetle infestation. Thus, the increases observed must be confined to the lands affected.

On the 133 square miles the increased water expected 95 percent of the time will range from 1.66 to 19.19 inches. Since the increases have been measured at a stream gage, it means that they are net increases after evaporation, transpiration, and other losses have taken place.

Using the measurements of the water content of the snow on April 1, the net increase in water on the 133 square miles can be illustrated.

From snow-storage studies at the Fraser Experimental Forest, interception of snow (water content) is 30 percent when open areas are compared to forested areas (8,9,10). The studies of snow interception were carried out in lodgepole pine and Engelmann spruce-alpine fir forests at elevations between 9,000 and 10,500 feet.

As measured in open parks, table 4 gives, at 8,500-9,000 feet elevation, a mean annual water content of the snow on April 1 after defoliation of 19.60 inches. Based on the studies at the Fraser Experimental Forest, the water content of the timberlands, had the trees not been defoliated, would be 30 percent less than in the open parks, or 13.69 inches. Because of defoliation, the water content of the timberlands is the same as in the open parks, as no great amount of snow is now lost through interception. Thus, both the parks and the timberlands had a mean water content of snow on April 1 of 19.60 inches, after defoliation.

The difference gives a net gain of 6.00 inches on the timberlands which suffered the beetle infestation.

To obtain an increase in total annual stream flow of 1.30 inches over the watershed from snow accumulation on April 1 would require a net increase in water of 7.45 inches on the 133 square miles of dead timber.

No precise measurements on the White River watershed are available to substantiate the calculated gain in water content of snow on April 1 on the 133 square miles. The above discussion illustrates a reasonable expectancy at elevations between 8,500 and 9,000 feet. The strongest fact is that the mean total annual stream flow of the White River has increased 1.82 inches (18 percent) as gaged at Meeker, Colorado. This increase is due to the beetle infestation and would not have occurred solely by changes in climate.

SUMMARY

During the years 1942-1945 a severe attack by beetles killed Engelmann spruce and lodgepole pine in the watershed of the White River in western Colorado. The area of dead trees amounted to 17.5 percent of the watershed. Questions have arisen as to the effect of areas infested by the spruce beetle on stream flow and watershed conditions.

The effect of beetles on the death of spruce causes changes along two lines:

1. by reducing snow interception which allows more snow to accumulate on the ground and thus increasing the supply of water available for stream flow, and
2. by cutting down the transpirational draft of the once live trees which used water in their growth.

Fluctuations in climate cause greater or lesser amounts of water to flow past stream gaging stations and so must be accountable for some of the stream-flow differences now observed at Meeker, the main gaging station of the White River. But not all of the changes in stream flow are due to year-to-year changes in the climate.

By using the stream flow of Elk River, the watershed of which has not been affected by a beetle infestation, an idea of the climatic changes may be obtained. When these changes are applied to the stream flow of White River, any residual effect may be attributed to the beetle infestation.

Using gaging-station records at Meeker, Colorado, for the White River, a drainage area of 762 square miles, and at Clark, Colorado, for the Elk River, a drainage area of 206 square miles, an analysis was made of the effects of the beetle infestation on the White River Plateau.

After adjusting for climatic changes it was found that the mean annual stream flow as well as the spring, and summer-winter flows of White River had increased as a result of the beetle infestation. Ninety-five percent of the time these increases will amount to 1.82 $\pm$ 1,53 inches, 1.27 $\pm$ 1.24 inches, and .58 $\pm$ .22 inch, respectively. Likewise, the mean annual flow of White River increased 1.30 $\pm$ 1.01 inches due to the water content of the snow on April 1.

Statistical analysis showed that these increases were not due to chance changes in climate.

Regardless of the exact figures, more water now passes the stream gage at Meeker than formerly. This means that the beetle infestation has had an effect on stream flow and, as a consequence, on watershed conditions.

Experiments in the spruce-fir and lodgepole pine types at the Fraser Experimental Forest (elevation 9,000 - 11,500 feet) have repeatedly pointed to the possibility of increasing water supplies through proper timber-harvesting methods (9,10). Such methods reduce interception of snow, reduce transpiration, and maintain the necessary control of soil erosion. The possibility of increasing water supplies by allowing more snow to reach the ground is demonstrated by the effects of the beetle infestation on the White River Watershed-an area of 762 square miles. The destructive effects of this increase is still to be ascertained. These effects are well controlled experimentally at the Fraser Experimental Forest (11).

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2. [illegible]

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On the White River Plateau, where the beetle devastation has been the heaviest, more water is present to cause damage by surface runoff and erosion on steep slopes formerly protected by dense stands of trees. In addition to the increased hazards of fire, there also exists the hazard of increased erosion. Thus, care must be exercised in the construction of roads, location of skid trails, and other disturbing features incident to the logging of the timbered areas.

Should the White River Watershed be burned by fire, serious consequences would result. No immediate protection to the soil on the slopes of the once-forested areas would be available so that during the first, and probably succeeding years, considerable erosion would occur. Erosion would lower the productiveness of the site for the growth of trees; it would reduce the quality of the water supply. Increased water supplies are of little beneficial use when clouded with excess sediment.

From the watershed standpoint, fire is the greatest hazard, with the construction of roads, trails, and skidding of logs the next. These, coupled with the possible damage uncontrolled water can do, leave the watershed of the White River in a delicate balance.

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SOUTHEASTERN FOREST EXPERIMENT STATION
DIVISION OF FOREST INFLUENCES

PROGRESS REPORT
January 1 - March 31, 1953

COWEETA HYDROLOGIC LABORATORY

Discharge Integrator

With 31 weirs in operation, one of the most time-consuming operations at Coweeta has been the computation of water yield. In an effort to better insure maximum efficiency of personnel and obtain fuller utilization of available funds, a discharge integrator was obtained on loan from the U.S.G.S. and tests were made to check its utility with rectangular and curvilinear chart records from 90° V-notch, 120° V-notch, and rectangular type weirs. The findings can be briefly summarized as follows:

1. The U.S.G.S. discharge integrator can be operated well within the limits of accuracy necessary for daily water yield calculations at Coweeta.

2. The problem of adapting integrator computations to curvilinear recorder charts (FW-1) has been solved.

3. The present rate of integrator computations on continuous strip records is 240 days of records per man-day of semi-technical labor. The rate on FW-1 curvilinear charts is approximately 30 to 60 days of record less per man-day than with the continuous strip records.

4. The actual setting up and testing of the rating curve and scale settings in the instrument is of sufficient complexity to require approximately 4 hours of a technician's efforts. The time requirement for this operation is fixed and, by keeping changes in set-up to a minimum through careful planning, the technical time involved at Coweeta is of little consequence in reducing efficiency of total output.

5. For each year that Coweeta operates its present stream gage network, an integrator would save 500 man-days of labor when compared with the method of picking points. This would amount to a savings of 1700 man-days on the total backlog of streamflow data that are unprocessed at present.

6. A comparison of integrator values with Form 6 values (SEFES Technical Note No. 34, pp. 35-47) shows only small differences between the two methods. The differences between computational methods are well within the limits of accuracy of the field installations.

7. The discharge integrator is not without error or limitations in use. The errors are--for the most part--operational in nature but some of the use-limitations are inherent in the machine. For example, the integrator cannot generally be used on chart reversals without completely re-setting the machine. Our experience also indicated that there is a tendency for the integrator to "slip" at very low heads and the calculated value is below the true value.

8. A report on the Coweeta integrator tests is available on a loan basis.

Watershed No. 13 - Changes in Yield With Regrowth of Forest

Analysis of the data from the 40-acre coppice forest 11 years after clear cutting in 1939 shows diminishing streamflow as the forest develops and transpiration increases. Changes in the seasonal pattern of water increases were analyzed, which indicated that cutting the forest vegetation affects the water balance throughout the year. Introduction of the time variable in a multivariate linear regression served to establish the trend in yield changes as the forest grew back.

In Table 1 the changes with time are brought out by arbitrary separation of the 11-year period into three sub-periods.

Table 1.--Average monthly increase in streamflow
Watershed No. 13

(In Inches)

Age period: Years	Month												Total
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	
1 - 3	0.52	0.87	0.97	1.23	1.18	1.07	1.00	1.08	0.94	0.79	0.80	0.64	11.09
4 - 6	0.45	0.64	0.82	0.98	0.90	0.95	0.86	0.84	0.63	0.56	0.52	0.43	8.58
7 - 11	0.37	0.43	0.65	0.72	0.62	0.81	0.73	0.60	0.40	0.35	0.30	0.26	6.24

By grouping the individual monthly values into the three independent hydrologic seasons, the data in Table 2 suggest that as a forest stand which has been clearcut grows back, changes will occur in the seasonal pattern of water yield increases.

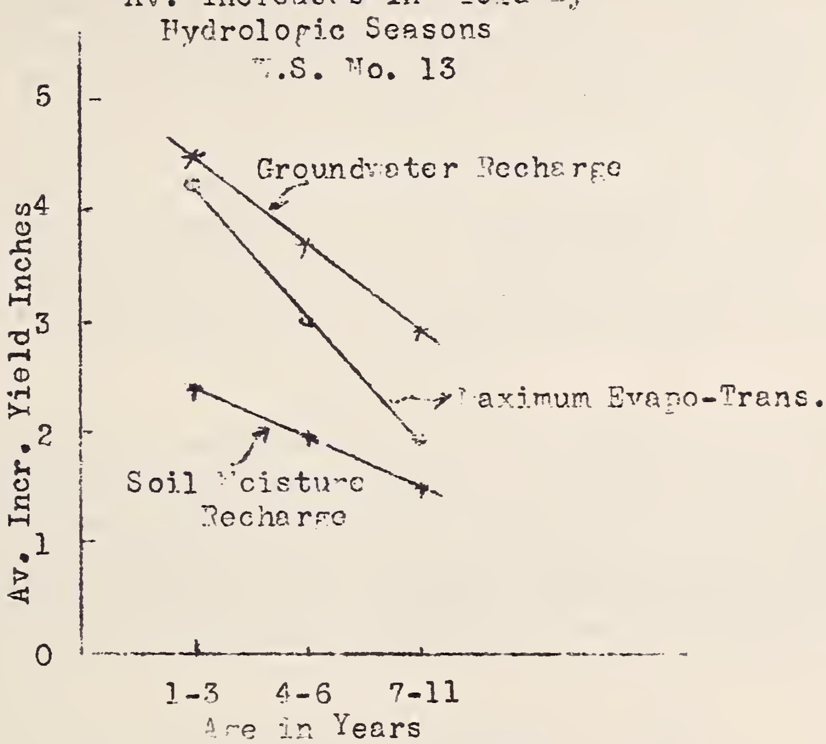

Fig. 1

Table 2.--Average increase in yield by hydrologic seasons
(In Inches)

Hydrologic Season	Months		Age in Years 1 - 3	4 - 6	7 - 11
Maximum evapo-transpiration	May - Sept.		4.25	2.98	1.91
Soil moisture recharge	Oct. - Dec.		2.36	1.91	1.45
Ground-water recharge	Jan. - Apr.		4.48	3.69	2.88
		Total	11.09	8.58	6.24

The graph of the plotted values in Table 2, Fig. 1, indicates that the recovery trend to date toward pretreatment yields is fastest for the growing season, May-Sept. The forest stand, as observed, is now showing less change from year to year and it is more than likely that the trend for this season will fall in line with the other two periods with time.

Test for Independence of Streamflow Data

Streamflow on the Coweeta watersheds is recorded continuously. For purposes of most analysis, however, the discharge is computed and summarized by monthly and yearly totals. These are used in many statistical analyses; for example, regression analysis is employed to predict streamflow on one watershed from that on another and tests of significance are made. In so doing it is important that the individual values of the sample be independent and do not exhibit serial correlation.

Quoting from A. Hald's "Statistical Theory with Engineering Application," page 760, "the importance of this assumption (that the observations are stochastically independent) has been only partly elucidated, but the theoretical investigations published so far indicate that the tests of significance may be highly misleading if the observations are even slightly correlated.

Ordinarily, annual totals of streamflow for a period of years, consecutive or otherwise, will be independent, showing random fluctuations from year to year. Monthly totals, on the other hand, are not independent and exhibit considerable serial correlation as can be seen from an examination of the data in Table 3. For example, it is evident that high values are followed by high values - low values by low values.

Table 3.--Streamflow,Watershed No. 2

(Monthly totals in area-inches)

Month	Water Year					
	1945	1946	1947	1948	1949	1950
Nov.	0.45	0.66	0.55	1.39	3.67	3.17
Dec.	0.77	1.59	0.72	1.45	4.59	3.42
Jan.	1.24	4.84	3.47	1.79	7.43	4.19
Feb.	1.90	5.86	2.36	4.91	5.91	5.14
Mar.	2.41	6.72	3.15	6.62	4.44	7.05
Apr.	3.47	4.69	3.96	6.00	5.03	4.02
May	3.02	5.25	2.54	2.62	5.58	2.61
June	1.16	2.51	1.25	1.34	4.87	1.93
July	0.66	1.48	0.65	1.42	4.13	1.42
Aug.	0.58	0.71	0.59	1.78	2.58	1.40
Sept.	0.64	0.54	0.80	0.81	2.53	2.77
Oct.	0.43	0.51	0.80	0.57	2.63	1.68
Yr. Total	16.73	35.36	20.84	30.70	53.39	38.80

L. R. Hafstead has presented a simple technique developed by J. Bartels for analyzing this persistence or correlation and adjusting for same. Those interested are referred to his paper, "On the Bartels techniques for time-series analysis, and its relation to the analysis of variance," Jour. of the American Statistical Association, 35 (210), Pt. 1, pp 347-361, June 1940.

Briefly, the test for independence is based on the fundamental proposition that if a variate is distributed with a standard deviation $\sigma^2(1)$ --unit deviation--then the standard deviation of the mean of a random sample of h such variates are given by

$$\sigma(h) = \frac{\sigma(1)}{\sqrt{h}}$$

That is, for independent observations the ratio

$$d_h = \frac{h\sigma^2(h)}{\sigma^2(1)}$$

should be statistically constant and equal to unity.

To run the test on the data presented we set $h = 2, 3, 4, 6, 10,$ and 12, respectively, Then beginning with November 1945 in Table 3, we find averages of each sample of h values taking the values consecutively. Thus for $h = 3$, we arrive at 18 separate averages, values from which $\sigma^2(3) = 3.864$ is then computed. For all values $\sigma^2(1) = 3.751$ and

$$d_3 = \frac{3(3.864)}{3.751} \quad 3.092$$

Similarly for the other values of h. The results of the computation are tabulated below.

Table 4.--Consecutive degrees of freedom

h values	Averages		
2	3.4254	3.7521	1.825
3	3.8645	3.7521	3.092
4	2.4237	3.7521	2.584
6	2.0383	3.7521	3.259
10	1.2720	3.7521	3.391
12	1.2110	3.7521	3.875

From Table 4 it appears that d_h is not equal to unity but asymptotic do $d_h = 4$, being rather constant above $h = 6$. See Figure 2. Now where H is any sample of h values sufficiently large, in this case over 6, we have that

$$H/4 = \frac{\sigma^2(H)}{\sigma^2(1)}$$

is statistically equal to unity. Using Bartel's phraseology in this example,

BARTELS TEST FOR INDEPENDENCE OF DATA

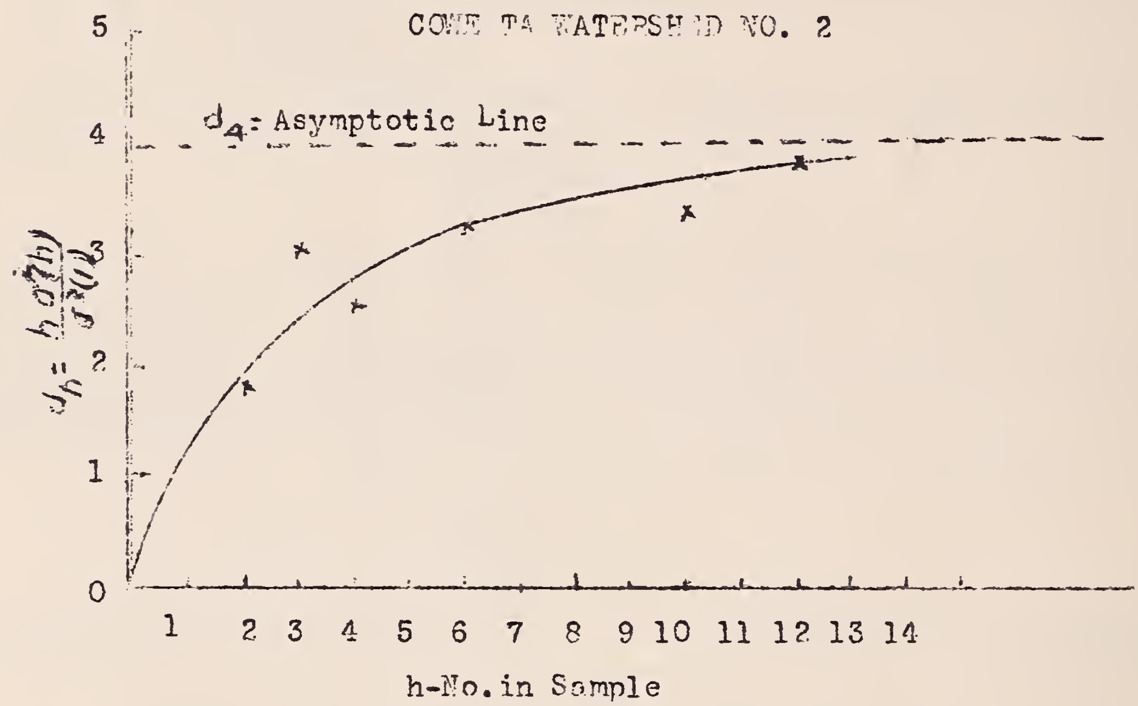

Fig. 2

we find there are H/4 effectively independent components among H successive values. This idea is generalized in Hafstead's paper.

From the above results it appears that instead of 72 independent values in Table 3, there are only 18 effectively independent components, and if we started out with 12 monthly values the reduction would be to 3 effectively independent components, which expressed in corresponding degrees of freedom might have a critical effect in tests of significance at a desired level.

The foregoing has a very interesting practical interpretation and verification. It is the usual practice in the Southern Appalachians to divide the water year into three periods as follows:

(1) Fall period of soil moisture recharge, Oct., Nov., Dec.
(2) Winter period of ground-water recharge, Jan., Feb., Mar., Apr.
(3) Summer period of maximum evapo-transpiration May, June, Jul., Aug., Sept.

There is some indication that September might be grouped with (1).

On the average the processes indicated in these periods operate independently in time. In other words, regardless of the degree of depletion of soil moisture during period (3), precipitation during period (1) is effective in replenishing soil moisture. During period (2) soil moisture is brought to field capacity and water tables rise to maximum level. During growing season, (3), soil moisture is rapidly depleted regardless of the precipitation and there is no accretion to ground-water tables. Streamflow data reflect these phenomena and the statistical analysis is greatly strengthened by introduction of this basic hydrology.

Hydrologic Notes

Climate

Table 5.--Climatic summary of air temperature and evaporation
Monthly Mean Air Temperatures

Month	Average		Maximum		Minimum		Monthly evaporation	
	17-Yr.	1953	17-Yr.	1953	17-Yr.	1953	17-Yr.	1953
	°F	°F	°F	°F	°F	°F	Inches	Inches
Jan.	40.2	40.5	51.0	51.9	29.3	29.1	1.15	1.30
Feb.	40.9	42.0	53.0	53.7	[illegible]	30.3	1.63	1.72
Mar.	46.8	48.5	59.8	62.0	33.9	35.0	2.81	2.98

Air temperatures for the first quarter were above normal or 17-yr. averages. Unseasonably warm weather in the middle part of March advanced the vegetative growth and together with desirable soil moisture conditions encouraged early planting.

Table 6.--Precipitation Summary

Month	17-Yr. Av.	1953	Deviation from average	No. of storms 17-Yr	No. of storms 1953
	Inches	Inches			
Jan.	7.22	9.23	+ 2.01	11	9
Feb.	6.65	10.39	+ 3.74	8	7
Mar.	7.99	5.65	- 2.34	8	7
Quarterly Total	21.86	25.27	+ 3.41	27	23
Water Yr. to Mar. 31	34.61	37.89	+ 3.28		
Cal. Yr. to Mar. 31	21.86	25.27	+ 3.41		

The pattern of subnormal precipitation which began in April of 1952 was broken in this quarter and there is an excess of 3.41 inches. Coweeta No. 8 rain gage at 3880 foot elevation recorded maximum precipitation of 14.32 inches for the month of February for all TVA gages. This was the heaviest February precipitation since 1944.

An unusually heavy wet snowfall on February 14-15 ranging up to 12 inches in the high country, caused considerable damage to power and telephone lines totalling $30,000 in all Western N. C. counties affected.

A heavy rainfall storm began about 10 p.m. on February 20 and ended around 5 a.m. on February 21. Highest recorded fall on Coweeta was 7.65 inches. Flood damage was small although the threat of extremely high peaks was maintained right up to the time of ending.

Quite heavy flooding occurred, however, in the Little Tennessee at Franklin, N. C.

Ground Water and Streamflow

Measurements from ground-water wells indicate that record low levels which occurred during subnormal rainfall and high temperatures of 1952 have been restored to the normal spring condition. Well No. 14 is a good indicator of ground water at lower elevations. The first quarter level normally reaches a maximum elevation of 2409.60 feet within a very narrow range of ± .05 foot. As of March 31 the water table stood at this figure.

Streamflow for the quarter was at normal levels reflecting recharge of ground water.

Vegetation

It appears that forest vegetation will leaf rather late this year due to frequent frosts at end of March. This will probably extend the fire season a week or two depending to some degree on April air temperatures.

Logging on Watershed No. 10

Watershed No. 10, Camp Rock Branch, 212 acres, is once again being logged for timber and pulpwood. Cutting began in March. This watershed is an experiment in complete exploitation of the forest stand as practiced in the Southern Appalachians with major emphasis on the effect of logging on water values. The following tabulation shows the schedule of cutting to date and products removed.

Period of Sale	Products Removed
May 1942 - March 1943	86 M Bd. Ft. Sawlogs
Jan. - June 1945	155 Cords Chestnut Extract Wood
Jan. 1947 - March 1948	161 M Bd. Ft. Sawlogs and 950 cords extract wood

It is expected that this sale will amount to 60 M Bd. Ft. sawlogs and 250 cords of pulpwood.

Measurements of water quality in terms of stream turbidities are continuing. Also the N. C. State Wildlife Cooperator will sample the stream for the effects of logging on the fish food population.

N. C. Wildlife Cooperative Study

Auxiliary stream temperature studies are under way in connection with the major food production study. Differences in food production have been found to date at various sampling points, some apparently associated with land use treatments on the watersheds, such as logging, some with cutting of riparian vegetation, and some under natural undisturbed conditions.

By collecting stream temperature data, an important variable affecting food production can be isolated and the differences analyzed to see if they are large enough to have any effect.

At the present time there are eight stations in operation, six with maximum and minimum thermometers and two using recording thermometers. It is intended that records will be collected for a minimum of 12 months.

The temperature study is part of three experiments dealing with effect of logging, cutting of riparian vegetation, and fertilization of stream on food production.

Location of Temperature Stations

1. Logging study - weekly maximum-minimum readings at stations on Shope Creek above and below mouth of logged Watershed No. 10.

2. Fertilization study - weekly maximum-minimum readings at stations on Ball Creek above and below mouth of Watershed No. 14.

3. Riparian vegetation - weekly maximum-minimum readings on Shope Creek above bridge on main road and at beginning of cleared area between office and cabins. Recording thermometers above and below the area along Shope Creek which was cut and treated with 2,4-D.

Table 7 is presented to show some results to date on the riparian study. Bottom samples of stream fauna were taken in the cleared and wooded areas. Significant differences in mean counts of the total number of organisms were obtained for the samples obtained in three of the four months.

Table 7.--Effect of cutting riparian vegetation on number of bottom fauna

Month	Oct. 1952		Nov. 1952		Dec. 1952		Jan. 1953	
Treatment	Cleared	Wooded	Cleared	Wooded	Cleared	Wooded	Cleared	Wooded
No. of samples	3	3	3	3	6	6	6	6
Total number organisms	248	97	242	249	253	69	268	96
Aver. number per Sq. Ft.	82.7	32.3	80.7	83.0	42.2	11.5	44.7	16.0

It should be noted that the wooded section of the stream was unusually low in production of bottom fauna as compared with other wooded sections on Coweeta where samples were taken. This low production may result from a tendency of the adult insects to lay eggs in the open section or to an actual migration of the immature insects into the open section of the stream. Either or both of these factors might create a paucity of organisms in the sections of stream immediately adjacent to the cleared area.

Cooperation - Universities

Professor Royal E. Shank at the Botany Department, University of Tennessee was supplied around 36 years of daily maximum and minimum air temperature records from 3 weather stations. After these data have been summarized plans are to use them in connection with theses and special cooperative studies that may be undertaken at the Laboratory.

In connection with the new course of Forest Influences at the University of Minnesota, Professor Donald Duncan has been supplied with considerable material for his lectures and data for laboratory problems.

At the request of Professor Earl J. Hodgkins, at Alabama Polytechnic Institute, Auburn, Alabama, a two-day training session was provided February 26 and 27 for students taking the Forest Influences course. One feature of this graduate course is that the 2-day intensive training session provided by the Coweeta Staff will be substituted for time normally spent on laboratory problems.

Johnson spent March 3 discussing Forest Influences with students and faculty members at Duke University and in the evening lectured to the Forestry Club on Watershed Management. Two lectures on watershed management were given March 5th at the School of Forestry, North Carolina State College. The visits and lectures were made to acquaint students and faculty members with Forest Influences and the cooperative research program that is available at Coweeta. These lectures completed part of the 1953 objective to visit all Forest Schools in the Southeastern Station territory during the calendar year.

Miscellaneous

Hursh Leaves Africa.--Dr. C. R. Hursh, who has been in Kenya, British East Africa, since February 1952 making a survey of the water and climatic resources of East Africa, left Nairobi, Kenya, around March 1. for return to the States. Hursh will travel by ship to Rome, Italy. Last reports are that he will visit hydrologic stations on the continent and stop to confer with many of the visitors who have been at Coweeta, finally arriving in London just before the Coronation. He will be expected back in Asheville around the latter part of June.

Visitors

Five groups, a total of 16, visited the Laboratory. This included a group of six Formosans under the auspices of OFAR and MSA.

Jesus Maria Lopez, of the University of Los Andes, Venezuela, arrived for an eight-week training session.

Movie "Waters of Coweeta"

There were four major showings of the Coweeta copy of the film away from the Laboratory before a combined audience of 265. The reception continues to be favorable and the film appears to be very well balanced in meeting the needs of groups with highly different interests, such as high school and college students, educators, scientists, conservationists, business men, foreign visitors, etc.

DIVISION OF FOREST INFLUENCES
SOUTHEASTERN FOREST EXPERIMENT STATION

PROGRESS REPORT

January - March 1953

PIEDMONT RESEARCH CENTER

General

No new work in influences was undertaken during the quarter at this Center. We are in the process of completing our soil moisture study using Fibreglas electrodes, which was started in the summer of 1950. Our intention is to summarize results for Departmental publication, and also to prepare shorter articles either for Journals or Station Papers. Results at the 12-year-old loblolly pine plantation were presented at the 1952 Soil Science Society meeting and will appear soon in the Proceedings. Interception and Stemflow measurements at that site have been published as a Southeastern Station Paper. Stemflow in young loblolly pine was found to be of considerable magnitude. The resulting concentration of rainfall at the tree bases causes uneven application of rainfall to the soil surface and complicates soil moisture sampling.

We are making an effort to set up studies to evaluate the effect of prescribed burning on soil and watershed conditions in the Piedmont. This is a team project with the Hitchiti Research Center to evaluate silvicultural aspects and general guidance from the Management, Fire, and Influences Divisions of the Station. Past work on prescribed burning on soil has generally yielded inconclusive results, and we are of the opinion that this is inevitable when the field plot type of experiment is used. There are so many variables uncontrolled and soil conditions themselves are far from uniform that there is little hope for clear-cut results.

We hope to break down the study into small parts which appear possible of solution. First we wish to determine what weight of litter is needed to prevent accelerated erosion under our intense rainfall. Also to be determined is the effect of organic matter content in the surface soil upon the erosion hazard. Our intention is to use infiltrometers for this study, but we expect to apply rainfall from a height of about 20 feet to better duplicate the impact of natural rain. If we can establish the critical amounts of litter and organic matter for broad soil groups we should be able to make reasonable predictions as to the effect of fire upon erosion and surface runoff. Our present information on litter fall under typical forest types makes it possible to estimate time needed for recovery.

It appears hopeless to measure a possible reduction in soil organic matter as a result of fire. At least, it would take many, many years to detect any change. We are thinking about investigating a possible change in quality of soil organic matter, but as yet are only pondering this.

It appears that biological studies should be pushed. It is hard to explain the rather loose permeable surface soil conditions under unburned Coastal Plain forests without attributing their creation to pine mice and other burrowing animals. Very likely the reduction in litter brought about by fire discourages such animals, and soils become more compact. We are searching for cooperation to help answer such questions.

Discussion

The Coweeta report for October - December discusses a phenomenon of high peak flows when soil moisture was low. The same type of event occurred there in November 1938. It is difficult to see how this can be explained by the "thatched roof" hypothesis. The same leaves were on the ground during December rains and must have been packed even tighter then than in November. A more likely explanation is the resistance to wetting shown by organic materials when they are at air-dry conditions. This is true of soil organic matter as well as of the F and L layers. All who have attempted to wet dry soils from the top in the laboratory must have run into the difficulty of trying to wet those high in organic matter. However, if the organic matter is wetted from below it gradually absorbs water, and finally shows no resistance to wetting. (The same applies, of course, to a kitchen mop.)

In Florida, "unwettable" soils have caused considerable concern to those irrigating citrus. I believe that after the extremely dry fall at Coweeta, the organic layers at the soil surface had become difficult to wet and actually repelled water over sizeable patches of the watersheds. Such conditions may occur rather frequently but are not observed because the first rains after a dry spell are more often of low intensity and serve mainly to slowly wet up organic materials.

In the same Coweeta report, it is stated that foliage production on the watershed which is annually cut (No. 17) is less than under the original stand. The basis for this statement is a figure of 5,680 pounds for annual leaf fall derived from a 1940 study. The 1940 study was made by collecting fallen leaves from the ground and attempting to decide in which year they dropped. This is admittedly an almost impossible job and the value obtained was too large. In more careful work at Bent Creek, Hursh found old growth hardwoods to drop about 4,000 pounds of leaves per year. Sims reported pine-hardwoods to drop from 2600 to 3100 pounds of leaves annually. At this Center, Metz has found a 150-year-old hardwood stand to have an annual litter fall of 4,000 pounds while two 50-year hardwood stands drop about 3500 pounds. The conclusion we would draw is that the one-year-old sprouts on Area 17 produce practically the same weight of leaves as the original stand. The weight of stems is large, and it appears that more organic matter is added annually to the soil surface than with the original cover. So far as water yield is concerned, the increased yield is probably due to (1) a shallower depth of rooting of sprouts and shrubs than the original forest, and (2) the reduction in transpiration caused by cutting back the sprouts in midsummer.

Several Stations report on experiments and observations concerned with the problem of erosion from logging. It is a question as to whether

there is any mystery about the process involved. Certainly when water falls upon or is concentrated upon bare soil, erosion will result regardless of soil series, method of logging, silvicultural system, or what have you. Field experiments to study sediment production from different logging systems are not apt to produce any really sound conclusions. A careless operator with a light tractor can do more damage than a careful man can do with a big machine. One trip to haul logs when a road is soft on one study watershed may cause enough erosion to invalidate designed comparisons between watersheds.

We do need a whale of a lot of research on logging methods themselves. The effort should be to develop logging methods that fit the timber and the terrain. Truck-cat logging schemes requiring long mileages of unsurfaced roads are bound to cause serious sediment production in mountainous country. Careful planning and supervised maintenance will reduce the erosion but from a practical view require more police work than can be paid for. Frequently, conventional logging schemes are also poorly adapted to the silvicultural system desired. Rather than devote too much time proving how bad logging can be and patching up defects in defective methods we should take a hard look at the whole problem. We have all seen big changes in logging methods in our working experience. We'll no doubt live to see even bigger changes. Yet, so far, logging methods are devised by loggers and equipment firms to solve <u>their</u> problems. Both Management and Influences workers need to get in on development work too to see that <u>our</u> problems are also solved.

Recommended reading for logging road researchers is "Soil movement as affected by slope, discharge, depth, and velocity of water," N. C. Agricultural Experiment Station Technical Bulletin 78, 1944.

The Crystal Ball

Roots and particularly how far down they go in various situations promise to give more and more of us greater concern. So far, this is a tough problem to handle. It is hard work and one can't always evaluate what he does observe. Tracer-elements may be a helpful approach. Their use is discussed for this purpose in the Proceedings of American Society for Horticultural Science, Vol. 55, pp. 27-34, 1950. North Carolina State College is granting a Ph.D to a forester this spring for work done with tracer-elements in trees. His name is Donald Moreland, and he can be reached through Dean R. J. Preston of the N. C. State College School of Forestry. He is highly recommended by all who have worked with him.

Of course, as soon as one becomes concerned with root depths he is forced to become curious about actual soil depths too. Particularly, is this true on experimental watersheds. If one knew where the deep and shallow soils were on a watershed and actually how much soil there was, it would be easier to explain a lot that is puzzling today. Here is another nasty job, but one we can't avoid much longer if we wish to deal with facts rather than abstractions. Engineers and others have also faced the same problem and devised means of attacking it. Among the more promising are light-weight boring and probing rigs. The electrical resistivity method appears particularly well suited for our purposes. Those of you at universities or other places where you can learn more about subsurface

exploration could help us all by looking into the subject. The Corps of Engineers has done a great deal of testing of such equipment at Vicksburg, and we should take advantage of their experience. It would be extremely helpful if either the direct methods or geophysical exploration could be tried out on an area such as Coweeta.

As knowledge of watershed management increases, it becomes increasingly obvious that we all face common problems. The fundamental questions are the same in California and in the Carolinas. We have spent too much time thinking about the minor differences and too little thought on the big similarities. Since the same general problems face all of us in the job of increasing knowledge in the field of influences, we could certainly benefit from a closer coordination of our research effort. All areas, of course, feel the need for better financing and no one can dispute this need. However, we must guard against using this for an excuse. It may be possible that we could achieve more by concerted efforts and good clear thinking than we could with another million dollars. This thought is stimulated by a recent article in Science (Vol. 116, No. 3017, pp. 439-443), "Dangers Confronting American Science."

Publications

Hoover, M. D. Interception of rainfall in a young loblolly pine plantation. Southeastern Forest Experiment Station, Station Paper No. 21, 13pp. Jan. 1953.

Hoover, M. D. and H. A. Lunt. A key for classification of forest humus types. Proc. Soil Sci. Soc. of Amer. 16(4): 368-370. Oct. 1952.

QUARTERLY REPORT
January-March 1953

Forest Influences Division
Southwestern Forest and Range Experiment Station

<u>Upper Rio Grande Research Center</u>

Two general meetings were held with the University of New Mexico and the New Mexico College of Agriculture and Mechanic Arts to present and discuss the rough draft of the problem analysis for the Upper Rio Grande watersheds. Two other meetings are planned in April to present the material to the Federal, State, County, and private interests. Extreme interest was shown in the assembled material on recent trends and developments.

<u>Evaluation of reseeding woodland and sagebrush ranges for waterflow retardation and soil stabilization in northern New Mexico</u>.--Deteriorated southwestern ranges have been reseeded primarily to increase forage production, with very little attention being given to other benefits that may result. Justification has been on increased forage yields which varied from two to over ten times those produced on adjacent native ranges. On the basis of range productivity alone, reseeding has proved economical and an important contribution toward the solution of the forage shortage during the early spring grazing period. Nineteen thousand acres have been reseeded to early growing crested wheatgrass in the New Mexico portion of the Upper Rio Grande basin, by the Forest Service. Two hundred thousand additional acres are scheduled for reseeding in this area to help alleviate the critical shortage of spring forage. The pinyon-juniper-sagebrush zone comprises two-thirds of the reseedable area, with the rest being in the ponderosa pine belt.

Secondary benefits of soil stabilization and water protection through increased infiltration and reduction in erosion rates by reseeding deteriorated ranges have been assumed, with no definite measurements being made.

The Rocky Mountain infiltrometer, a rainfall-simulator, was used to determine the effect of recommended reseeding practices on soil physical conditions and vegetation and the relation to infiltration and erodibility. Range-watershed conditions were sampled which include reseeded and adjacent native ranges under grazing and nonuse, when available. The study was started in 1952 and is scheduled for completion in 1953. Infiltration-erosion results obtained during July and August 1952 on four sites at three general locations in the woodland-sagebrush zone are summarized below. Data are for 50-minute periods of artificial rainfall applications at 3.50 inches per hour which approximates the maximum intensity of the 50-year cloudburst storm.

(Over)

Cebolla Mesa - 15 miles north of Taos, New Mexico

Soil: Silt-loam to clay loam alluvium derived from igneous and metamorphic rocks.

Herbage cover at time of sampling (after grazing)

	Ground cover (grass & weeds) Percent	Forage (grass) yield (air-dry) at time of sampling Lbs./acre
Native - Livestock excluded - 11 yrs.	1	12
Native sod - grazed by cattle	0	0
Reseeded - Livestock excluded - 6 yrs.	10	227
Reseeded - grazed by cattle	2	1/ 82

Blue grama dominant grass on native range and crested wheatgrass on reseeded range.

	Infiltration rate (inches per hour) Start of runoff to end of run	Last 20 minutes
Native - livestock excluded	1.25	1.03
Native - grazed by cattle	1.08	.82
Reseeded - livestock excluded	1.17	1.01
Reseeded - grazed by cattle	1.02	.88

	Erosion index (tons per acre per inch of surface runoff)
Native - livestock excluded	2.20
Native - grazed by cattle	2.03
Reseeded - livestock excluded	2.11
Reseeded - grazed by cattle	1.87

1/ If this area had not been grazed, forage yield would have been 170 (from known utilization).

Glorieta Mesa - 6 miles south of Rowe, New Mexico

Experimental Planting

Soil: Silt-loam to sandy clay loam, residual, derived from limestone.

Herbage cover at time of sampling

	Ground cover (grass & weeds) Percent	Forage (grass) yield (air-dry) Lbs./acre
Native - livestock excluded	12	217
Native - grazed	7	158
Reseeded - livestock excluded	10	311
Reseeded - grazed 3 years 1948-50 (Not grazed in 1951 and 1952)	6	130

Blue grama dominant grass on native range and crested wheatgrass on reseeded area.

	Infiltration rate (inches per hour) Start of runoff to end of run	Last 20 minutes
Native - livestock excluded	1.28	1.12
Native - grazed	1.17	.96
Reseeded - livestock excluded	1.07	.90
Reseeded - grazed	.93	.78

	Erosion index (tons per acre per inch of surface runoff)
Native - livestock excluded	.63
Native - grazed	.46
Reseeded - livestock excluded	1.08
Reseeded - grazed	.84

Glorieta Mesa - 6 miles south and 5 miles east of Rowe, New Mexico

Administrative Planting - Valle Grande

Soil: sandy clay loam, residual, derived from sandstone.

Herbage cover at time of sampling

	Ground cover Percent	Forage yield Lbs./acre
Native - grazed	20	560
Reseeded - grazed	26	522

	Infiltration rate (inches per hour)	
	Start of runoff to end of run	Last 20 minutes
Native - grazed	0.97	0.61
Reseeded - grazed	.93	.61

	Erosion index (tons per acre per inch of surface runoff)
Native - grazed	0.70
Reseeded - grazed	.54

Corona site - 20 miles northwest of Corona, New Mexico

Soil: fine sandy loam, residual, derived from limestone

Reseeded - sand dropseed

Native - blue grama and galleta

Herbage cover at time of sampling

	Ground cover (grass & weeds) Percent	Forage yield Lbs./acre
Native - Livestock excluded - 13 years	30	343
Native - Livestock excluded - 6 years	42	1,013
Native - grazed	25	544
Reseeded - Livestock excluded - 6 years	45	1,684

	Infiltration rate (inches per hour)	
	Start of runoff to end of run	Last 20 minutes
Native - livestock excluded - 13 years	1.78	1.66
Native - Livestock excluded - 6years	.87	.73
Native - grazed	.72	.62
Reseeded - livestock excluded - 6 years	1.52	1.49

	Erosion rate (tons per acre per inch of surface runoff)
Native - livestock excluded - 13 years	0.18
Native - livestock excluded - 6 years	.39
Native - grazed	.33
Reseeded - livestock excluded - 6 years	.50

While the study has not progressed sufficiently to formulate conclusions, the present results indicate reseeding has not increased the erodibility of the soil or decreased infiltration.

Exclusion of livestock on both native and reseeded areas resulted in an increase in infiltration; the amount appears to be dependent on the length of time under protection. The effect of grazing on soil erodibility is not definite, having caused a decrease on two sites and an increase on one site. Further evaluation of soil physical factors may explain these results. It is possible that site differences overshadow treatment effects.

On the basis of present data, it cannot be said that reseeding deteriorated ranges under present acceptable practices for forage production results in increased infiltration and reduced soil erodibility in the woodland-sagebrush zone of northern New Mexico. On steep sloping lands and highly erodible soils where soil stabilization and water protection are prime objectives, reseeding practices incorporating water retention measures in ground preparation such as pitting and basin listing should be considered. Establishment of a denser cover of herbaceous vegetation should also be considered for soil stabilization at some sacrifice in volume of forage produced where watershed values are paramount.

Sierra Ancha Research Center

Plans were completed at Sierra Ancha for measuring the water and sediment yields in the intermediate-water-yielding areas. Several large lysimeters and the Natural Drainage Watersheds will be used to measure the comparative water and sediment yields with a grass cover and with a predominant shrub cover, under different soil conditions.

Preliminary to replacement of shrubs with grass on two of the Natural Drainage watersheds, a plot study was installed to determine whether ammate or a 2,4-D., 2,4,5-T mixture, applied as a basal spray and as painted on the cut shrub stems during both dormant and actively growing seasons, is the most effective in killing the shrubs.

Density and composition of the vegetation on the Natural Drainages have changed during the 17-year period 1935-1952.---The Natural Drainage watersheds at Sierra Ancha were fenced in 1935. Soon after 24 meter-square quadrats were established to follow changes in vegetation resulting from the proposed grazing treatments. Six quadrats were located in each watershed on six different site conditions. These quadrats were charted in 1935, 1936, 1940, 1942, and 1952.

Comparisons of vegetation change between watersheds, summarized in table 1, show that grass density on all four watersheds remained fairly similar during the ungrazed pretreatment period from the 1935 charting through the 1942 charting. In 1935 the range in grass density between the watersheds was from 1.58 percent on Watershed C to 2.15 percent on Watershed D. In 1942 the range was from 6.13 percent on Watershed A to 7.44 percent on Watershed C. Between 1942 and 1952 the quadrats on all watersheds lost grass density. Those on heavily grazed Watershed A lost the most (83 percent) and those on ungrazed Watershed C lost the least (46 percent).

Density of forbs and shrubs varied erratically between watersheds, from only a slight increase during the entire period on Watershed C to a tremendous increase on Watershed A. Meter-square quadrats are not well adapted to the measurement of shrubs, but the record of shrub and half-shrub increase on these quadrats is an important item in interpreting vegetation changes that have occurred.

Table 1.-- Average percent density, Natural Drainage quadrats

	Watershed A Heavily grazed since 1942 ✯			Watershed B Ungrazed ✯			Watershed C ungrazed ✯			Watershed D Moderately grazed since 1939 ✯		
	Gr.	Fo.	Sh.	Gr.	Fo.	Sh.	Gr.	Fo.	Sh.	Gr.	Fo.	Sh.
1935	1.87	0.09	1.41	1.60	0.08	0.01	1.58	0.07	2.03	2.15	0.03	2.23
1936	3.27	T	1.77	2.80	.02	2.38	2.76	.10	2.19	3.76	.03	5.35
1940	5.92	.04	8.54	5.07	.50	1.88	5.42	.09	1.18	5.39	.04	2.16
1942	6.13	.02	10.66	6.29	.18	1.72	7.44	.05	2.26	6.39	.14	5.68
1952	1.06	.17	30.15	2.01	1.81	3.35	3.98	.04	2.14	2.86	2.04	9.42

Gr. - grass Fo. - forbs Sh. - shrubs

✯ Includes half-shrubs, cacti, trees, and shrubs.

Table 2.— Summary of grass composition - Natural Drainage quadrats

	Composition as percent of total for each year									
	Watershed A					Watershed B				
	1935	1936	1940	1942	1952	1935	1936	1940	1942	1952
Sideoats	82.77	75.99	76.51	79.54	73.98	55.44	54.64	58.99	59.36	35.62
Hairy grama	15.51	20.11	17.16	15.26	26.02	30.35	33.99	28.31	33.88	49.13
Black grama	0	0	0	0	0	0	0	0	0	0
Threeawns	.74	3.30	3.47	2.48	0	4.32	4.35	8.00	3.92	6.13
Cane beardgr.	.98	.60	2.13	2.04	0	9.89	6.78	3.86	2.15	4.56
Tex. timothy	0	0	0	.68	0	0	.24	.84	.69	4.56
Sprangletop	0	0	0	0	0	0	0	0	0	0
Others	0	0	.73	0	0	0	0	0	0	0
	Heavily grazed since 1942					Continuously protected since 1934				
	Watershed C					Watershed D				
	1935	1936	1940	1942	1952	1935	1936	1940	1942	1952
Sideoats	67.91	66.71	86.62	88.24	96.07	61.36	51.46	55.25	48.33	50.70
Hairy grama	24.42	28.11	9.69	10.24	1.46	24.12	30.75	20.35	20.20	16.53
Black grama	0	0	0	0	0	12.25	16.86	21.71	29.46	32.01
Threeawns	.38	.30	.14	.11	2.18	1.90	.40	.06	.13	.12
Cane beardgr.	2.84	0	0	.04	.29	.37	0	.25	.39	0
Tex. timothy	0	2.05	.99	1.03	0	0	.53	1.61	1.49	.47
Sprangletop	4.45	2.83	1.81	0	0	0	0	.49	0	0
Others	0	0	.75	.34	0	0	0	.28	0	.17
	Continuously protected since 1934					Moderately grazed since 1939				

<u>Effect of climatic variations not decisive during 1935-1952 period.</u>— The increase in grass density (see table 1) from 1935 to 1940 was made under somewhat unfavorable precipitation conditions, and was probably due largely to a change in vigor of the previously overgrazed grass plants. Release from grazing pressure permitted the individual plants to attain a highly vigorous growing condition in the years following fencing. Summer precipitation was from 17 percent to 31 percent below average for four consecutive years (1936-39) and total annual precipitation was from 1 percent to 27 percent below average in four of the six years (1936 and 1938-40). Above average summer precipitation in 1940 and the extremely high precipitation in the winter of 1940-41 (180 percent of average) gave the already vigorous grass plants a big boost as shown by the 1940 and 1942 chartings.

<u>Competition and drought are dominant causes of reduction in grass density.</u>— During the 1935 to 1942 period of increasing grass density competition between different plant growth forms was a minor factor. Forb, half-shrub, and shrub density increased at about the same relative rate as grass density. And grass density on the quadrats exceeded total forb, half-shrub, and shrub density for each of the four chartings from 1935 through 1942, comprising from 51.54 percent to 60.16 percent of the total density during this period.

Sometime between 1942 and 1952 competition from half-shrubs and shrubs, coupled with unfavorable precipitation conditions (four consecutive years, 1947-50, with both total annual precipitation and summer precipitation from 6 percent to 52 percent below normal) allowed the balance to swing heavily in favor of the shrubs. During this period grass density on the quadrats decreased two-thirds while forb and shrub density increased two and one-half times. Summer drought gives the half-shrubs and shrubs a considerable competitive advantage over the perennial grasses because half-shrubs and shrubs make most of their growth in the spring when soil moisture, even in drought years, is nearly always sufficient for their use. In years of deficient summer precipitation, perennial grasses lose vigor and density quickly because they depend on this precipitation to make their growth.

Changes in soil and vegetation 5 years following a chaparral fire.— On June 17, 1947, a fire started by lightning burned over 7,200 acres of chaparral land near Four Peaks about 4 miles above Roosevelt Dam in Arizona. This area is composed mainly of granite soils which are some of the most erodible soils in the Southwest.

Immediately after the burn permanent photo points were established to follow the vegetation recovery. After the fire there was no living vegetation above the ground on the area. Charred and blackened stubs of stems of the chaparral species and a layer of ash covering the ground were the only evidence that the area had been vegetated.

In spite of the steep slopes and erodible nature of the soil, the vegetation was in control of the site prior to the burn; slopes were smooth and stream channels showed little evidence of accelerated gullying or sediment deposition. Two months after the fire an extensive system of steep-walled erosion rills had developed on the slopes and erosion debris had changed the round-bottomed drainages at the foot of the slope to wide, debris-filled channels. A large part of the erosion debris had lodged in the channels awaiting flash flood waters to flush the sediment into Roosevelt Reservoir. Basal sprouts of many of the shrub plants were already a foot or more long at this time.

A check of the area in September 1952 showed that most of the chaparral species sprouted profusely. Shrub live oak (Quercus turbinella) was the dominant species. Laurel sumac (Rhus ovata) made a more vigorous growth than the oak but does not occur in dense stands. Mountainmahogany (Cercocarpus montanus) and Emory oak (Q. emoryi) have sprouted to some extent. Contrary to general belief, manzanita (Arctostaphylos pungens) and desert ceanothus (Ceanothus greggi) apparently were completely killed by the fire. Practically all grass in the area prior to the burn was completely killed and has not recovered to any extent. On the other hand, a dense stand of sprouting chaparral shrubs, with little or no herbaceous species in the intershrub species, appears to be occupying the site.

Stream channels are still filled with unstable sands and gravels which are being carried closer to the reservoir with each succeeding flood flow. The effects of this fire in lost grazing capacity and increased sediment moving into the reservoir promise to be felt for many years.